Water Supply and Water Management in the Metal Ages

Edited by

Dirk Brandherm and Thomas Zimmermann

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Cover: Aerial view of the motilla of Azuer (Daimiel, Ciudad Real) in 2013 – Luis Benítez de Lugo Enrich and Miguel Mejías Moreno

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Sponsors Preface

The Importance of Archaeology in the Search for Scientific Evidence to Understand the Past

As an individual committed to the pursuit of quality scientific knowledge in archaeology, it is an honour to contribute to the edition of the papers presented at the 'Metal Ages 2022' colloquium. This event was co-organized by the UISPP's Scientific Commission 'Metal Ages in Europe and the Mediterranean' and the Department of Archaeology at Bilkent University, and held at Bilkent University in October 2022. This took place while we were still grappling with the aftermath of the COVID-19 pandemic, and I had restricted my international travels to the bare minimum.

E2IN2 S.A. supports archaeology through collaborations with archaeologists in Spain and Spanish archaeological missions abroad. This support typically involves multi-year actions and the signing of agreements with both public and private institutions.

We also collaborate in the publication of books and manuals in the field, to contribute to the dissemination of archaeological knowledge.

We decided to attend the Metal Ages conference given our involvement in the inaugural lecture on the Motilla culture. A unique culture specific to certain areas of the Iberian Peninsula, it has been a focus of our dissemination efforts for several years. We aimed to highlight our interest in promoting awareness of this earliest known European culture to utilize water resources, especially during a time of persistent drought due to a global phenomenon.

This is the first time we have participated in a publication that is not purely Spanish, capturing the multidisciplinary experience and knowledge about a period during which our ancestors were becoming humanized, leading to the different civilizations from which we descended.

My attendance at the conference was very enjoyable, despite the injury I suffered during the visit to the site on the last days of my stay in Turkey. I sincerely appreciate the care and attention given to me in person.

I extend my thanks to the organizers and the individuals from the university whom I had the opportunity to meet, as well as for the support I received after the minor mishap.

We hope that in the future, other opportunities will arise to actively collaborate in initiatives that contribute to the dissemination and enhancement of archaeological heritage, ensuring its understanding and preservation by and for future generations.

Madrid, May 17th, 2024
Valentín de Torres-Solanot
Civil Engineer / CEO E2IN2

Editors' Foreword

Since its foundation in 1931, the inherent philosophy of the International Union of Prehistoric and Protohistoric Sciences (UISPP) was — and today, almost a century after its inception, still is — to foster, promote and publicize the global exchange of archaeological knowledge across modern political borders and language entities. It was therefore not a daring experiment but a logical consequence to hold the annual meetings of the UISPP Metal Ages and Archaeometry commissions for the first time in Ankara, Türkiye, from October 13th to 16th, 2022. The Department of Archaeology at the internationally renowned Bilkent University hosted the joint colloquium, with 'Water Supply and Water Management in the Metal Ages' as the covering topic for the Thematic Session organized by the Metal Ages Commission. The General Session accommodated talks delivered by members of both commissions.

The presented papers and posters, ringed in with the keynote lecture on the Motilla culture by Luis Benitez de Lugo Enrich (Universidad Complutense, Madrid) encompassed a wide range of topics pertaining to diverse issues concerning water supply (or negotiating its shortage) in pre- and protohistoric times. The papers delivered in the General Session likewise displayed the broad variety of current archaeological debates that can be further enriched with methodologies and applications rooted in physics and chemistry.

The two conference days held in the large auditorium of the Humanities and Letters Faculty of Bilkent University allowed for a vivid exchange of ideas, the reviving of old friendships and the establishment of new ones, all further invigorated by field trips to the Hittite fortress of Gavurkalesi and the UNESCO World Heritage site of Gordion, and, last but not least, the multilayered marvels of traditional and contemporary Turkish cuisine.

The present volume contains the early harvest from both the Thematic and the General Session. We would like to extend our sincerest thanks to the Rector of Bilkent University, Prof. Dr Kürşat Aydoğan, the Provost Prof. Dr Orhan Aytür, the Dean of the Faculty of Humanities and Letters, Prof. Dr Simon Wigley, and the Head of the Department of Archaeology, Prof. Dr Dominique Kassab-Tezgör for providing the conference venue and funding for the evening reception, further honouring our event with their welcoming speeches. Additional funds for the snack supply during session breaks were kindly provided by Valentín de Torres Solanot. We would further thank all contributors for their excellent papers, and, once again, Valentín de Torres Solanot and E2IN2 for their generous contribution towards the publication costs of the present proceedings.

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Thematic Session:
Water Supply and Water Management in the Metal Ages

Evidence for roof drainage at the Early Bronze Age site of Dhaskalio, Cyclades

Marie Floquet, Michael J. Boyd and Colin Renfrew

Recent excavations on the central Aegean site of Dhaskalio have revealed an impressive site-scale drainage system running below a complex network of streets and buildings, offering new insights into water management in the Early Bronze Age Cyclades. Micromorphological and phytolith studies have provided valuable information on roofing form and construction techniques (Gkouma *et al.* 2022). However, the use of flat roofs in combination with such an extensive water management system forces us to address roof-water management. While no buildings are preserved to roof level, excavated evidence for the use of drainage channels suggests how the overhead extension of the drainage system would work. In addition, the discovery of several pipe-like terracotta cylinders in the roofing debris of one of the excavated buildings suggests a special case of roof drainage.

Keywords: Early Cycladic architecture, roof drainage, water management engineering, early urbanisation, Keros, Early Bronze Age Cyclades

Les fouilles récemment entreprises sur le site égéen de Dhaskalio ont révélé un impressionnant système de drainage à l'échelle du site, sous le réseau viaire mais aussi dans les bâtiments, qui offre ainsi de nouvelles perspectives sur la gestion de l'eau dans les Cyclades au début de l'âge du Bronze. En parallèle, les études micromorphologiques et l'analyse des phytolithes ont fourni des informations précieuses concernant la forme des toitures et leurs principes constructifs (Gkouma et al. 2022). L'emploi de toits plats, associé à un système de gestion des eaux aussi élaboré, interroge sur la façon dont les eaux de toiture étaient gérées. Bien qu'aucun bâtiment ne soit conservé jusqu'au niveau du toit, la découverte de systèmes d'évacuation à la base des murs de certains édifices suggère que ce type de dispositif pouvait également être utilisé pour les toitures. Surtout, la découverte de plusieurs cylindres en terre cuite en forme de canalisation, dans les débris de toiture d'un des bâtiments du site, évoque l'existence de techniques de drainage plus spécifiques.

Mots-clés : Architecture du Cycladique Ancien, drainage des toits, gestion de l'eau, urbanisation précoce, Kéros, Cyclades à l'âge du Bronze ancien

Orta Ege'deki Dhaskalio'daki yapılan son kazılar, karmaşık bir sokak ve bina ağının altından geçen, alan ölçeğinde etkileyici bir drenaj sistemini ortaya çıkarmış ve Erken Tunç Çağı Kikladları'nda su yönetimine yeni bakış açıları sunmuştur. Mikromorfolojik ve fitolit çalışmaları çatı kaplama formu ve inşaat teknikleri hakkında değerli bilgiler sağlamıştır (Gkouma ve diğ. 2022). Ancak, bu kadar kapsamlı bir su yönetim sistemi ile birlikte düz çatıların kullanılması, bizi çatı suyu yönetimini ele almaya zorlamaktadır. Hiçbir bina çatı seviyesine kadar korunmamış olsa da, drenaj kanallarının kullanımına ilişkin kazılan kanıtlar, drenaj sisteminin tavana doğru uzatılmasının nasıl çalışacağını göstermektedir. Buna ek olarak, kazılan binalardan birinin çatı kaplama enkazında birkaç boru benzeri pişmiş toprak silindirin bulunması, özel bir çatı drenajı durumuna işaret etmektedir.

Anahtar Kelimeler: Erken Kiklad mimarisi, çatı drenajı, su yönetimi mühendisliği, erken kentleşme, Keros, Erken Tunç Çağı Kiklad Adaları

Introduction

Water management in the Middle and Late Aegean Bronze Age has been widely discussed for decades, mostly in relation to Mycenaean and Minoan architecture (Betancourt and McCoy 2012; Cadogan 2007; Driessen and MacDonald 1988; 1990; Flood and Soles 2014; Gorokhovich *et al.* 2011; Kountouri *et al.* 2013). It has been shown to be a major area of architectural innovation and engineering as early as the protopalatial period (Nowicki 2011; Schmid and Treuil 2018). Specifically, the use of roof drainage systems in Minoan vernacular architecture has been well-established through excavated architecture, clay models and iconographic depictions (Lenuzza 2013; Shaw 2004).

Water management in the third millennium Aegean, on the other hand, is still poorly understood, for a simple reason: compared to the extensively excavated and well-understood Minoan built environment, evidence of water management in Early Bronze Age Aegean settlements is scarce, although not entirely absent. Until very recently, the few architectural devices excavated showed very little investment in terms of technical innovation or resource management. Drains known from Poliochni are not in themselves clear indicators of complex planning or organization (although the settlement in general shows some evidence for early urbanization: Cultraro 2007). In the Cyclades, the settlements of Kastri (Bossert 1967; Marthari 2017) and Panormos (Angelopoulou 2007; 2008; 2014) have thus

far revealed no signs of water management, while the drain excavated at Markiani (Marangou *et al.* 2006) was rudimentary in its building technique and certainly not a manifestation of a sitescale water management strategy. Until recently, the only clear evidence for more complex hydraulic engineering was at the settlement of Skarkos on Ios, where the excavators identified drains running across the site from the top of the hill to the exterior of the settlement (Marthari 2018).

Recent excavations at the Early Bronze Age settlement at Dhaskalio, off the western end of Keros in the Cyclades, have revealed a complex and site-scale water-management system involving a variety of impressively well-built architectural devices, offering a new understanding of Early Bronze Age water management in particular and civil engineering in general. It has also offered some intriguing hints as to roof-water management, even though no building is preserved to roof level at Dhaskalio.

The architecture of Dhaskalio

The Early Bronze Age site of Dhaskalio is located on a small, particularly steep islet situated around 90m to the west of the today-uninhabited island of Keros in the Small Cyclades (Renfrew *et al.* 2013). Facing the area of Kavos, known for its 'special deposits' of broken marble figurines and vessels (Renfrew *et al.* 2012; 2013; 2015; 2018), it was originally linked to the island by a now submerged isthmus (Dixon and Kinnaird 2013). The pottery and radiocarbon dates suggest a long occupation of the site, starting early in the 3rd millennium and ending near the transition to 2nd millennium BCE. The site had come to the attention of archaeologists in the 1960s, following an episode of looting on Kavos, facing Dhaskalio. Subsequently, some preliminary excavations were undertaken on Dhaskalio under the direction of C. Doumas (Doumas 1964; 2007; 2013). Much more extensive operations were undertaken on Dhaskalio between 2007 and 2008 (Renfrew *et al.* 2013), revealing the existence of a large and densely built Early Bronze Age complex (Boyd 2013). These discoveries confirmed the need for a second campaign, carried out between 2016 and 2018 (Renfrew *et al.* 2022).

The settlement, covering around 1.3ha, is particularly densely built and was set in the naturally steep and rocky landscape by means of a massive site-scale concentric terracing system encircling the islet below the summit on the north, east and south sides (Fig. 1). The overall layout therefore takes a roughly radiocentric form, dictated by the natural topography and the construction of the terracing system. The terraces are composed of large retaining walls that contain a packing of limestone cobbles mixed with earth, on which the buildings were then constructed. The latter are rectilinear in shape. Their walls are mainly made of blocks of marble imported from Naxos, although some earlier walls utilise local material (aeolianite and limestone) extracted either from the bedrock on Dhaskalio or from nearby on Keros. Stone was the principal building material, sealed with different sorts of clayey binding material. Roofs were made of thick layers of clay mixed with various types of temper (Gkouma *et al.* 2022). Communication between the different terraces levels was made possible by the mean of radial stepped streets (as well as perhaps movement on roof spaces), while we expect the densely-set buildings to be reached by concentric paved streets. It is therefore apparent that the complex is characterized by directed urban planning and advanced architectural engineering.

Water management

One of the most impressive architectural expressions of this planning and advanced engineering can be seen in the management of water, which required the development of complex architectural devices, combined systemically to work at all scales from individual built space to the whole site.

In particular, the site was endowed with a site-scale drainage network running under, and so planned along with, the built streets of the settlement. These drains usually take the shape of built channel, 0.15m to 0.20m wide, lined by two walls built of Naxian marble (Fig. 2). The covers of the drains – which form the pavement of the streets - are made of large flat marble slabs. Feeding into this principal drainage network, individual buildings are regularly endowed with evacuation systems destined to drain water away from open spaces toward the streets (Fig. 3). Some of the buildings excavated thus far were equipped in the base of one of their façade walls with an evacuation system that allowed their residents to empty waste-water from the inside of the building directly toward the communal drainage network.

This seemingly disproportionate architectural investment demonstrates how crucial water management was to the builders and dwellers of the site. The steepness of the islet, combined with the relative absence of soil to absorb rainwater, makes the complex particularly vulnerable to erosive processes. This statement is further apposite considering that the EBA Aegean was considerably wetter than it is nowadays (Finné *et al.* 2011; Weiberg *et al.* 2016).

The micromorphological study undertaken on site, coupled with a geo-ethnoarchaeological study of traditional Naxos and Kato Kouphonisi farm buildings, suggest that the roofs of the settlement were flat

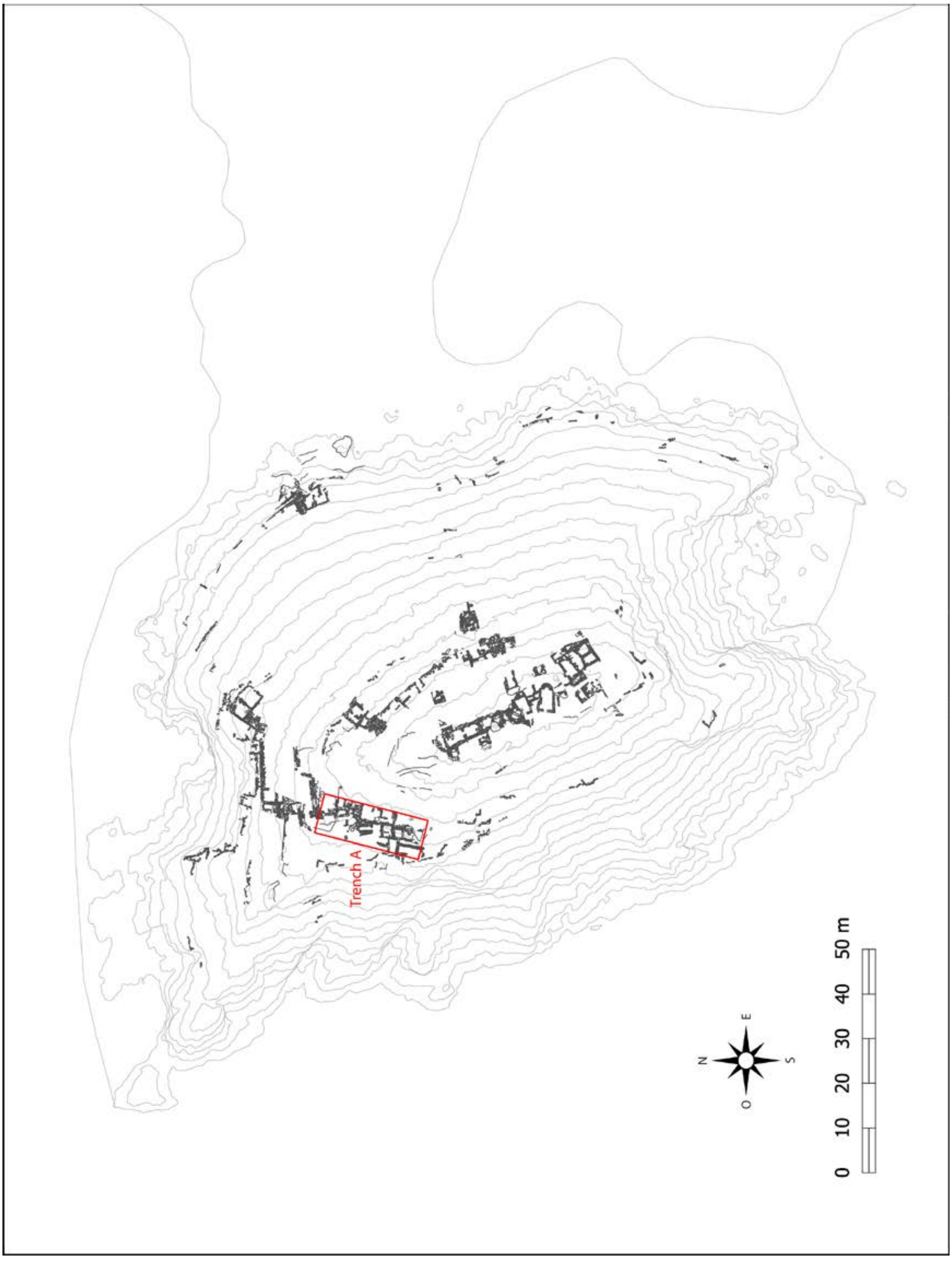

Fig. 1 – The Early Bronze Age settlement at Dhaskalio. – (Plan: Keros Project).

Fig. 2 – Drainage systems under the streets of Dhaskalio. – (Photo: Keros Project).

Fig. 3 – Evacuation system leading toward a street. – (Photo: Keros Project).

(Gkouma *et al.* 2022). Gkouma *et al.* have demonstrated that, supported by beams of juniper, olive or occasionally imported wood (Ntinou 2013), roof substrates were formed of reed or palm as well as probably juniper branches; slabs of marble or schist could be placed above these layers of vegetation; and the roof was sealed with layers of clay (often with calcareous or lime inclusions). The clays may have been in layers with different properties, and were probably frequently resurfaced or repaired. The occasional presence of charred material and anthropogenic inclusions in the roof sediments, along with frequent finds of artefacts, might indicate that the roofs were sometimes used as activity areas.

The choice of flat roofs for the buildings does raise the question of rainwater management. The study by Gkouma *et al.* suggests a tendency to use water-tight materials in the upper surfaces of roofs. Nonetheless, flat roofs are not ideal for evacuating water in case of heavy rain, and hence often require specific devices to channel and evacuate water. At Dhaskalio in particular, where it seems that some roofs may have been used as activity areas, this problem must have been crucial. Minoan engineers later solved this problem with various techniques. One of them consists in surrounding roof terraces with a parapet in which were set terracotta pipes (Lenuzza 2013; Shaw 2004). Rainwater, contained by the parapet, could easily be channelled toward the outside of the building through the pipes. The existence of such a system has been suspected as early as Early Minoan I in Crete, based on the house model unearthed in Hagia Triada (Todaro 2003).

Naturally, roofs of clay, timber and stone are subject to decay and are not preserved *in situ* at Dhaskalio, so any drainage system cannot be observed directly. We can only speculate about the form that such devices may have taken. A simple rupture in the stone masonry of a low parapet might have been sufficient to evacuate water from terraces. A slightly more complex drainage system, similar in its techniques of construction to the evacuation system unearthed in Trench H (Fig. 3), might have perhaps been in use. Here, a large slab is set at ground level and partly built under the wall directs water to a channel running through the wall over a length of 0.80m. On the other side, the water simply spills onto the slab floor of the alley. Under the floor, a well-constructed drain collects the water and leads it down to the sea, outside the complex. We might infer that most roofs on Dhaskalio employed a similar arrangement: a channel through a low parapet leading the water to spill down onto a street, under which it entered the drainage system and was led out of the settlement. One disadvantage of such a system might be weakening of the simple earth mortar of the wall at the point where the water drained toward the street, if the water were simply allowed to run down the wall (though this could have been subject to regular repair in dry seasons). Alternatively, a stone projecting from the egress of the roof conduit, such as one of the numerous small stone discs found on site, would have directed some, at least, of the water off the face of the wall. The discovery of three pipe-like terracotta objects among the collapse layers of one of the buildings of the settlement of Dhaskalio could further suggest the localised usage of a more complex system.

The terracotta cylinders

The building in question is situated in Trench A (Fig. 4), on the relatively flat area that flanks the summit of the islet, to the northwest. It was accessible from a neatly paved street to the north. The limits of the building remain unclear, but on the ground floor it consists of three spaces covering an area of about 7.00 × 3.50m, and it may well have been constructed over two terraces, whereby the rooftop of the ground floor was level with the adjacent terrace uphill, as seen elsewhere on Dhaskalio, and as also is the case with most buildings at Skarkos, the large EC II settlement on Ios (Marthari 2018). The lower part of the building, composed of at least two rooms, was accessible from the street through a narrow corridor (0.82 × 3.50m) running in parallel with a staircase that allowed access to the next terrace. The full extent of the western wall is not entirely clear. A stepped threshold marked the northern entrance of the building while preventing water ingress. The upper storey of the building might have been composed of two wings: one on the upper terrace, and the other above the two rooms below. There is clear evidence for activity on this upper level, although this could also be interpreted as activity taking place on the open roof, if the west part of the building were only single-storey. This upper part would have been accessible from the street in the north through a built staircase leading both to the upper terrace and to the now collapsed rooftop (or second level) above the ground floor. Apart from the presence of the staircase, the collapsed rooftop (or upper level) and the associated activities were clearly identified through the stratigraphy and micromorphological analysis (Gkouma *et al.* 2022).

The three pipe-like terracotta cylinders were found in the lower part of the building, one in the northern corridor, the two others in the northeast corner of the southern room (Fig. 4). They are closely similar in shape, dimensions, and technique of manufacture (Fig. 5). They take the form of a cylinder between 0.15m and 0.17m in length, with an external diameter of approximately 0.06m to 0.07m. The cylinders are pierced along their entire length by a hole of 0.01m to 0.03m diameter. In two cases, the opening at one end is slightly wider than that at the other. In the case of 11030 and 11007, one end is slightly flared. This same extremity presented

Fig. 4 – Plan of Trench A showing the location of the three pipes. – (Plan: James Herbst).

a very regular face. The ends of the cylinders are flat, with no means to aid the attachment of one to the other. The walls of the objects are particularly thick and the perforation narrow. It must also be noted that the surface is quite rough, perhaps only partly preserved. The study of their fabrics suggests that all three of them may have been made on Ios.

Found close to contexts associated with metallurgical activities, specifically lead working, they were initially suspected to be tuyères. However, although tuyères of this form are known from other regions in the Bronze Age, this is not a form represented in the Aegean at this time, and the shape of the artefacts is completely unlike the other tuyères found on site (Georgakopoulou 2013). The latter, much shorter (less than 0.07m), usually have a characteristic conical shape which allows the introduction of a pipe through which one can blow. This variation in shape could be explained by the use of a different ventilation system in which the pipe would be replaced by a bellows. But it could also be explained by a difference in function of these artefacts. The fact that all three of these terracotta cylinders were finds in roofing debris, precisely where the presence of a rooftop has been confirmed, brings the alternative possibility that they might have acted as roof drainage. In addition, pXRF analysis conducted on the pipes showed no raised levels of Cu or Pb, although not all ceramics used in metallurgy will necessarily do so. If we imagine that the second level of this building was a terrace-like open space used as a surface for activities, the question of water evacuation would have been significant. It is therefore tempting to imagine in this particular instance that a low parapet rising above

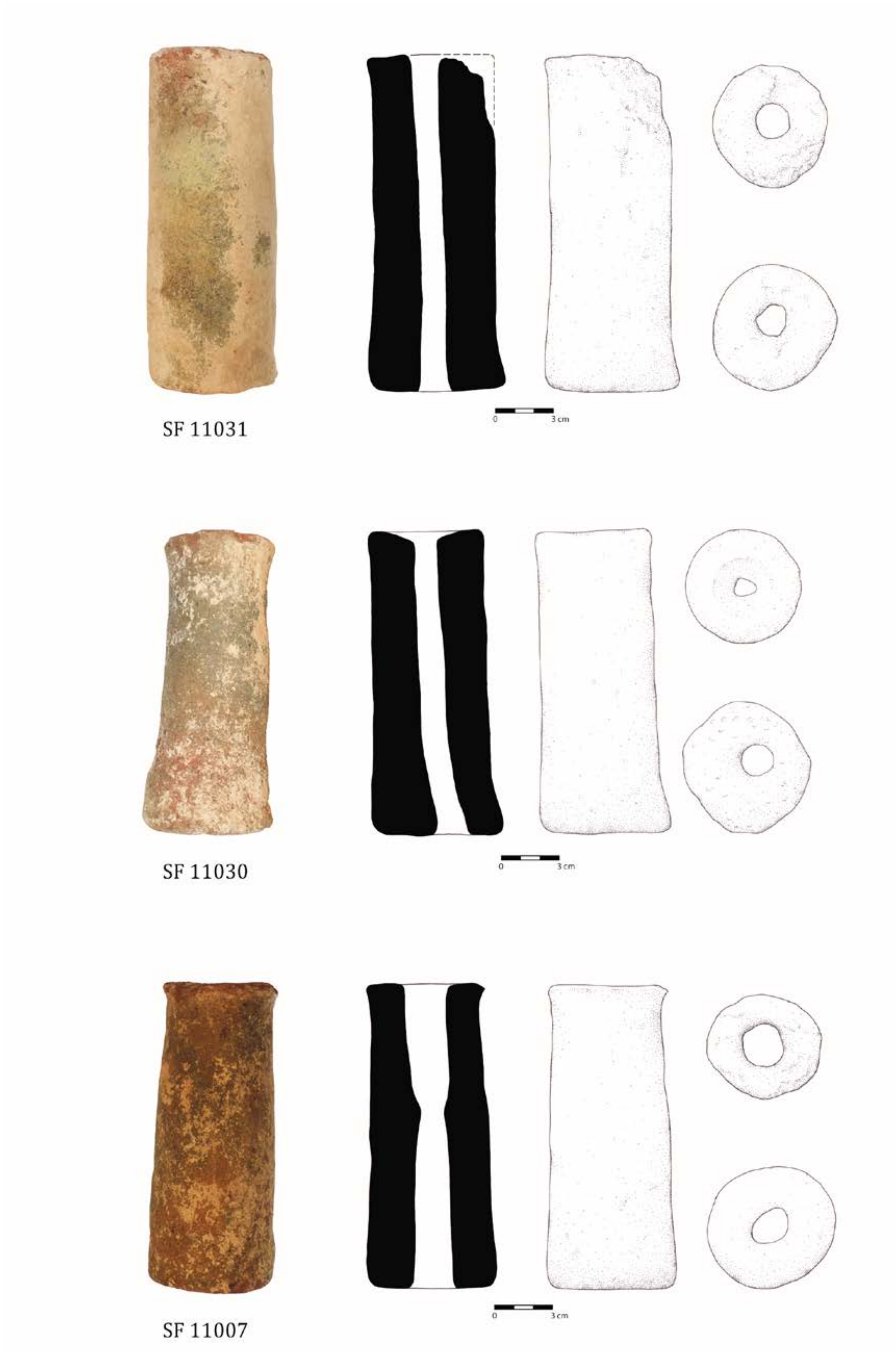

Fig. 5 – Three terracotta cylinders. – (Drawings: Céline Murphy).

Find N°	Context	Dimensions (cm)		
		Length	Diameter (int.)	Diameter (ext.)
11007	Room A04	15.7	1.8 – 2.3	5.8 – 7.0
11030	Room A04	15.7	1.2 – 1.8	6.1 – 6.9
11031	Room A06	17.8	1.6	6.4 – 7.0

Fig. 6 – Location and dimensions of the pipes. – (Authors' design).

Fig. 7 – One of the pipes in wall and roof debris in Room A04. Looking north. – (Photo: Keros Project).

the level of the roof was pierced not just with a simple channel for water egress, but with the three terracotta pipes, in a slightly more sophisticated version of the system we must assume was used site-wide (Fig. 6).

The careful excavation and study of the collapse and post-depositional processes in this building may provide some insight into the possible original position of these pipes. The two first pipes (SF 11007; SF 11030) were found next to each other in the northeast corner of the southern room (Fig. 4) in a layer containing roof debris. The western wall of the room, made of Naxian marble slabs, had almost fully collapsed toward the east. The use of a thick clayey component as a binding material helped partially to preserve the arrangement of the masonry. The two pipes were found in proximity with the upper part of the collapsed wall (Fig. 7). It is therefore tempting to suppose that their original position was in the northwest corner of the room, on top of this western wall. If so, the pipes would drain water away from the rooftop to a possible exterior space next to the room. It is also conceivable that a large vessel such as a pithos, were it placed under the pipes, could have been used to collect the water for reuse.

The third pipe was uncovered in the northern corridor entrance of the building, against the façade wall bordering the external second level access staircase. The collapse layers here indicate that this wall and the roof it was supporting collapsed toward the inside of the corridor. It is therefore tempting to restore the original position of the pipe on the street side. The pipe would, in this case, drain rainwater from the rooftop toward the outside stone staircase. The flow of water would then be led onto the northern paved street where a small gutter would evacuate it to the west.

The possibility that the cylinders were used as roof drainage does however raise several questions. First, the small diameter of the duct of the pipes (less than 3cm)

may, at first glance, seem inadequate for evacuation as it could easily get clogged and might be overwhelmed by the volume of water during an inundation. Minoan roof conduits rarely measure less than 0.15m (Shaw 2004: fig. 7). However, two examples of anthropomorphic Minoan gargoyles found in room IX of building Z of Zakros, in Crete, with an opening of less than 1.5cm in diameter, demonstrate that the use of such pipes is possible (Lenuzza 2013: fig. 9; Platon 1995: fig. 1). This interpretation was nevertheless criticized by N. Platon who, for the reasons we have just mentioned, preferred to see it as a conduit for a fountain or a cistern rather than a roof drain (Platon 1995: 771). Yet, if we consider that at Dhaskalio the use of such a drainage might have been a first experiment, we need not be surprised at a lack of finesse in the device. A similar arrangement has not been found elsewhere on site, and so was clearly unusual. The limited diameter of the duct also has the potential advantage of increasing the pressure of the water flow, so that the water would flow directly onto the street (or into a vessel) rather than down the wall, with its potentially erosive effect. This is in fact one of the principal utilities of gargoyles (Aurenche and Callot 1977: 93).

Second, the cylinders constitute unique artefacts both on site and in the wider Cycladic world, and their function necessarily remains uncertain. Similar artefacts have been found in the later Early Minoan III–Middle Minoan II 'Oval House' at Chamaizi, Siteia (Crete) (Lenuzza 2011: 65–66; Xanthoudides 1906: 144–145). V. Lenuzza does indeed link these artefacts to a roof channelling system (Lenuzza 2011: 65). The shape of the roof drain varies slightly from the terracotta cylinders of Dhaskalio, but it does make a good argument for the use of roof drainage system during these early periods.

Third, the context of discovery, on a settlement mainly characterized by metallurgical activities (Renfrew *et al.* 2022), with different processes in use through the lifetime of the settlement and evidence for experimentation, would make the tuyère hypothesis the most simple and thus perhaps the most convincing one, despite the lack of evidence in pXRF analysis. Even so, an original use as tuyères does not prevent their opportunistic reuse as roof drains in a subsequent phase of occupation. The settlement in general shows considerable evidence for artefact re-use and functional variability. This last explanation may be the most compelling, as it highlights the ingenuity of the inhabitants and their ability to adapt and innovate in the face of environmental factors such as the intensification of rainfall that seems to characterize the beginning of the third millennium BCE.

Conclusions

The recent study by Gkouma *et al.* (2022) confirms the long-held suspicion that Cycladic Early Bronze Age roofs were flat, and moreover strongly suggests that some effort was made to use a watertight clay mix in the upper layers. This alone suggests that roof drainage was an issue for which solutions would have to be found. The complex and planned nature of the site at Dhaskalio shows water management played a central role in site planning and engineering. A comprehensive system of sub-street drains was associated with internal, building-specific drainage systems, some of which conducted water over complex routes to meet the sub-street drains. It is clear therefore that roof drainage would have been as carefully considered and as well-managed as the other aspects of drainage for which we now have abundant evidence. A system of low parapets and conduits seems suited to the centralised system of drainage in operation, and enhanced an upper domain where flat roofs may not only have been activity locales but also may often have been used for inter-terrace communication. The three pipes discussed in this paper may represent a simple experiment in improving this system, or perhaps were part of a water collection system whereby rainwater could be channelled to storage vessels for reuse. Although a freshwater source was located nearby on Kavos, the advantage of gathering rainwater near the summit, perhaps as a supplementary supply, lay in not having to transport the water from sea level; the rainwater may also have been fresher than the available spring water. Future research at Dhaskalio will further illuminate the complex urban planning evident at the site.

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Water management at Pseira, Crete, in the Late Bronze Age

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Pseira is a small offshore island near the northeastern coast of Crete in the Aegean Sea. It was inhabited during the Minoan period from ca. 3000 BC to about 1200 BC. As the climate of this part of the Aegean became dryer during the second millennium BC, the residents built a complex water management system to catch and store rain water. The system was constructed in two ravines near agricultural terraces. Each ravine had a large stone and soil dam built as a massive double wall between the sides of the ravine with the space between the walls filled with packed soil and stones. Both uphill and downhill from the dams were smaller informal check-dams to slow the water flow and save smaller amounts of water.

Keywords: Minoan Crete, prehistoric water management, landscape archaeology, climate change

Pseira est une petite île au large de la côte nord-est de la Crète, dans la mer Égée. Il a été habité pendant la période minoenne à partir d'env. 3000 avant J.-C. à environ 1200 avant J.-C. Alors que le climat de cette partie de la mer Égée devenait plus sec au cours du deuxième millénaire avant J.-C., les habitants ont construit un système complexe de gestion de l'eau pour récupérer et stocker l'eau de pluie. Le système a été construit dans deux ravins à proximité de terrasses agricoles. Chaque ravin avait un grand barrage en pierre et en terre construit comme un double mur massif entre les côtés du ravin, l'espace entre les murs étant rempli de terre tassée et de pierres. En amont et en descente des barrages, il s'agissait de petits barrages de contrôle informels destinés à ralentir le débit d'eau et à économiser de plus petites quantités d'eau.

Mots-clés : Crète minoenne, gestion de l'eau préhistorique, archéogéographie, changement climatique

Chrysokamino, Girit'in kuzeydoğusundaki kıyıda MÖ üçüncü binyılda gelişen bir bakır eritme yeridir. İşçiler Kiklad adalarından ithal edilen bakır cevherini eritmişlerdir. Cevher eser miktarda arsenik içerdiğinden, elde edilen bakır da az miktarda bu metalı içeriyordu. Arsenik ayrıca arsenik alaşımı oluşturmak için bakıra kasıtlı olarak eklenmiştir çünkü saf bakır, oksijen varlığında açık kalıplar kullanılarak iyi dökümler oluşturmaz. Bunlardaki doğal arsenik miktarı, Bronz Çağı arsenik bakırındaki doğal safsızlıkları kasıtlı ilavelerden ayırt etmek için %2 arseniğin bir kılavuz olarak kullanılmasını önermektedir.

Anahtar Kelimeler: Girit, Minos, bakır, izabe, arsenik, arsenik, metalurji, Chrysokamino

Pseira is a small offshore island in the Aegean Sea, located just northeast of the isthmus of Ierapetra in eastern Crete, Greece (Figs. 1 and 2). It was initially explored in the first decade of the 20th century by an American archaeologist, Richard Seager, who excavated part of a Minoan harbour town (Seager 1910). He found that the prehistoric residents of Pseira were part of the wider Minoan culture of Bronze Age Crete. Then in the 1980s and 1990s, a Greek-American partnership led an archaeological campaign with an international team of specialists who more fully excavated the Minoan town, an associated cemetery, and a few other small buildings and installations scattered in the landscape (Betancourt and Davaras 1995; 1998; 1999; 2002; 2003; 2009; Floyd 1998; McEnroe 2001). The entire island also was surveyed intensively, revealing human habitation extending into the Byzantine period (Betancourt *et al.* 2004; 2005).

The island measures about two kilometers in length from east to west (Fig. 3; Betancourt and Davaras 1995: xxi, fig. 3). Its northern coast is steep, and cliffs rise there well above the water while the southern coast is lower and well-protected from northern winds (Farrand and Stearns 2004: 19, ill. 5).

A small settlement was founded on Pseira at the end of the Neolithic period, before 3000 BC (Betancourt and Hope Simpson 2004: 7), and it gradually grew over the millennia into a bustling seaport by the Late Bronze Age. The main part of the town was sited on a small peninsula facing south toward Crete (Figs. 3–6; Betancourt and Davaras 1995: 1–2, figs. 1, 2; 2009: 2, ill. 1.1; Farrand and Stearns 2004: 14, 19, ills. 2, 5; Hope Simpson and Betancourt 2004: 11, ill. 1, pls. 2, 3; Betancourt *et al.* 2005: pl. 25A). Because the peninsula extends away from the main part of the island of Pseira, its orientation creates a shelter from eastern and western winds, making this part of the landscape the best local place for anchoring ships (Davaras *et al.* 1992: 263, 264, figs. 38.2, 38.3; see also endpapers of Betancourt and Davaras 1998). The houses were constructed on this peninsula where the

Fig. 1 – Location of the small island of Pseira near Crete in the Aegean Sea. – (Satellite photo adapted from and courtesy of Google Earth, accessed May 8, 2023).

Fig. 2 – Eastern Crete with sites mentioned in the text. – (Satellite photo adapted from and courtesy of Google Earth, accessed May 8, 2023).

Fig. 3 – View from the northwest of the island of Pseira with the northeastern coast of Crete in the background. The topographic features of the island include the cliffs on the northern side in the foreground and the downward slope toward the southeast. – (Satellite photo adapted from and courtesy of Google Earth, accessed May 8, 2023).

Fig. 4 – Location of Pseira in relation to the northeastern coast of Crete. – (Satellite photo adapted from and courtesy of Google Earth, accessed May 8, 2023).

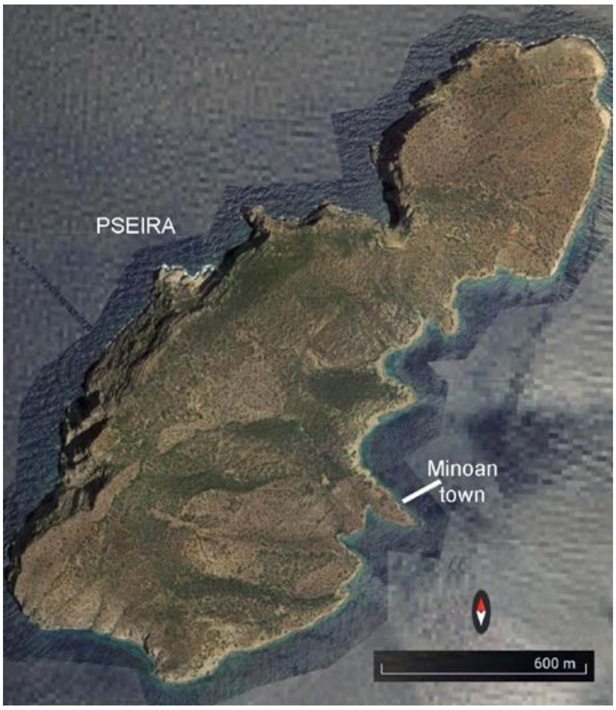

Fig. 5 – Location of the Minoan town on the island of Pseira. – (Satellite photo adapted from and courtesy of Google Earth, accessed May 8, 2023).

inhabitants would have easy access to the sea because of its close proximity to the natural harbour (Fig. 6; Betancourt and Davaras 1998: pls. 1, 2A; Betancourt *et al.* 2005: pl. 25A). The Minoans constructed a grand stone staircase that connected the harbour to the central part of the town (Fig. 6; Betancourt and Davaras 1998: 4–6, fig. 6, pls 2B, 3; McEnroe 2001, pl. 16; Betancourt *et al.* 2004, pl. 8A).

The community gradually increased in size (McEnroe 2001: 11, 14, 66, 67, figs. 9, 11, 50, 51). The residents of Minoan Pseira built their houses primarily of the readily available local limestone, phyllite, metacarbonate, and mudbrick (McEnroe 2001: 30–31). By the Middle Bronze Age, they were intensively farming the island (Betancourt 2005: 286–290). In addition to agriculture, the town was an active seaport, with trading by boat to receive goods like objects of pottery and metal that were not available locally because Pseira has neither metallic deposits nor banks of clay that would have been suitable for making ceramics (Hadjidaki-Marder 2021). These commodities and many others must have been received from the main island of Crete, where nearby Minoan towns such as Mochlos and Gournia were probably trading partners among other local settlements.

The town on the island of Pseira was quite prosperous by the middle of the second millennium BC, when the residents had Knossian-style wall paintings and pottery decorated with double axes and other typical Minoan motifs such as the Marine Style and other aspects of the Special Palatial Tradition (Seager 1910: 21–34, figs. 6–14, pls V–IX; Müller 1997: 300–301; Shaw 1998: 64; Jones 2024). Many other items help prove that Pseira was an integral part of the Minoan culture (i.e., stone vessels, Seager 1910: 34–38).

Studies of pollen history from lake sediments in Crete show that this part of the eastern Mediterranean had more rainfall when Pseira was first settled at the end of the Neolithic than occurs in the present day (Bottema 1980; Moody 2000; Bottema and Sarpaki 2003). As the centuries passed, the climate gradually became dryer, making farming more difficult (aridity began around 2200 BC, see Manning 2017: 451–454; see also Clark 2004: 31–33). Today, Pseira is a very dry island, and few trees grow on the small landform. The pines and other large trees that were present during the Bronze Age will no longer grow there because it is too dry. As

Fig. 6 – View looking northeast at the Minoan town of Pseira. Note the grand staircase at left leading from the harbour up to the centre of town. – (Photo: S. Ferrence).

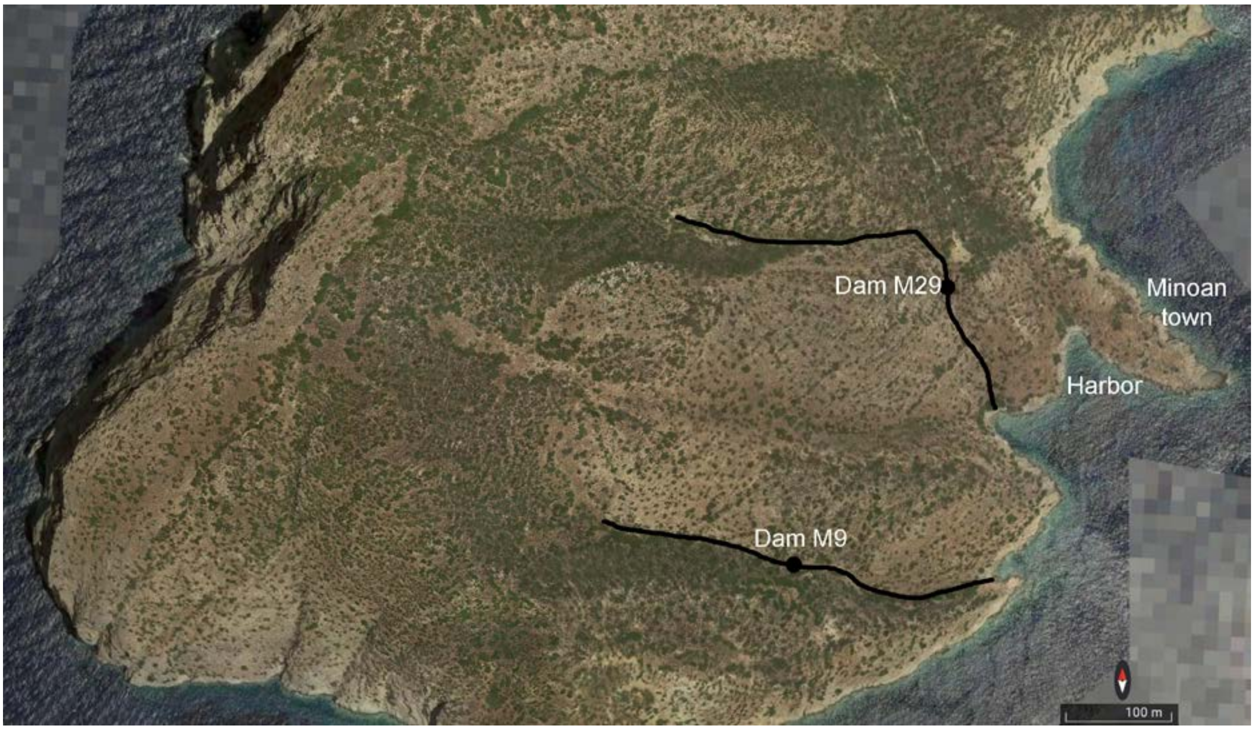

Fig. 7 – Locations of the two excavated Minoan dams in the southeastern part of the island of Pseira. – (Satellite photo adapted from and courtesy of Google Earth, accessed May 8, 2023).

the climate became drier during the middle centuries of the second millennium BC, the Minoans living there developed a water management system to help the situation. This system was mapped and studied as a part of the archaeological project that excavated the Minoan settlement and surveyed the island in the 1980s and 1990s (Hope Simpson 2005; Betancourt 2012).

Pseira is a rocky island with a rugged central portion that rises over 200m above the coast (Figs. 3, 5; Betancourt *et al.* 2005: fig. 1). By the Late Bronze Age, the Minoans were extensively terracing the hilly landscape in order to improve their yield (Hope *et al.* 2005). Agricultural exploitation on the island required this technique to create level plots of ground for farming. The animal bones and the carbonized seeds that were collected from the excavations show that the Minoans who lived there supported themselves by raising crops and keeping animals, mostly sheep and goats (Betancourt 2012: 17–21). Both aspects of their agrarian economy required water.

No permanent above-ground water supply exists on Pseira, and the residents would have had to depend on wells or on water conserved from rains. Several ravines extend from the high ground that forms the northwestern part of the island to the sea at Pseira's southeastern coast (Figs. 7–9; Betancourt 2012: 10, fig. 10). When the rains come, especially in the spring, water flows down these ravines to reach the sea, and in the early centuries when the climate was wetter, the ravines would have been temporary creeks with running water for a few days after a rainstorm. Two of these ravines were exploited for a water-management system that would have saved the water for human use (Fig. 7).

The main feature of each ravine's water-management system was a massive rock and earth dam constructed completely across each ravine about midway between its beginning near the top of the hill and its end at the sea (Figs. 9, 10; Betancourt 2012: 40, fig. 27). The bedrock at this side of the island is a gray limestone with white veins of calcite. The bedrock can be broken easily into large blocks that were used for the main part of dam construction. The two dams were built in the same way.

They were not found intact (Betancourt *et al.* 2005: pl. 25B–37). Each dam consisted of the surviving two ends, and many of the stones from the bottom of the constructions, plus a gigantic tumble of fallen stone on the downhill side where a terrific water pressure had broken through the massive constructions at some point between when they were built and their modern investigation (Betancourt 2012: 29, fig. 16). Presumably after Pseira Island was abandoned, the soil within the dams had slowly eroded away through the tiny gaps between the large blocks until the construction was weakened enough that a deluge from a gigantic storm broke through and washed away the centres of the two dams.

Fig. 8 – View down Middle Creek Ravine just south of Dam M29. – (Photo: S. Ferrence).

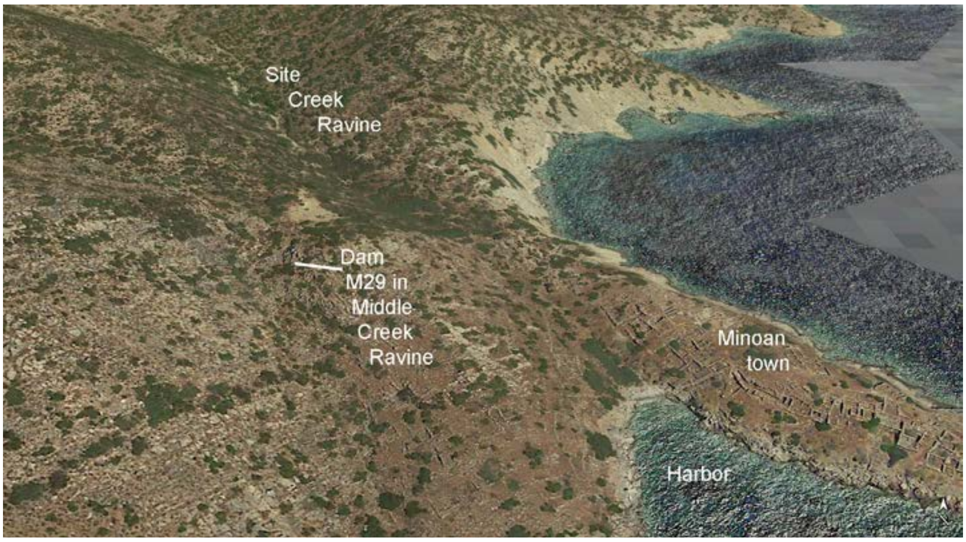

Fig. 9 – Aerial view of two ravines, including Dam M29, in relation to the location of the settlement and harbour. – (Satellite photo adapted from and courtesy of Google Earth, accessed May 8, 2023).

Fig. 10 – Tanya McCullough standing at the eastern side of Dam M29. – (Photo: S. Ferrence).

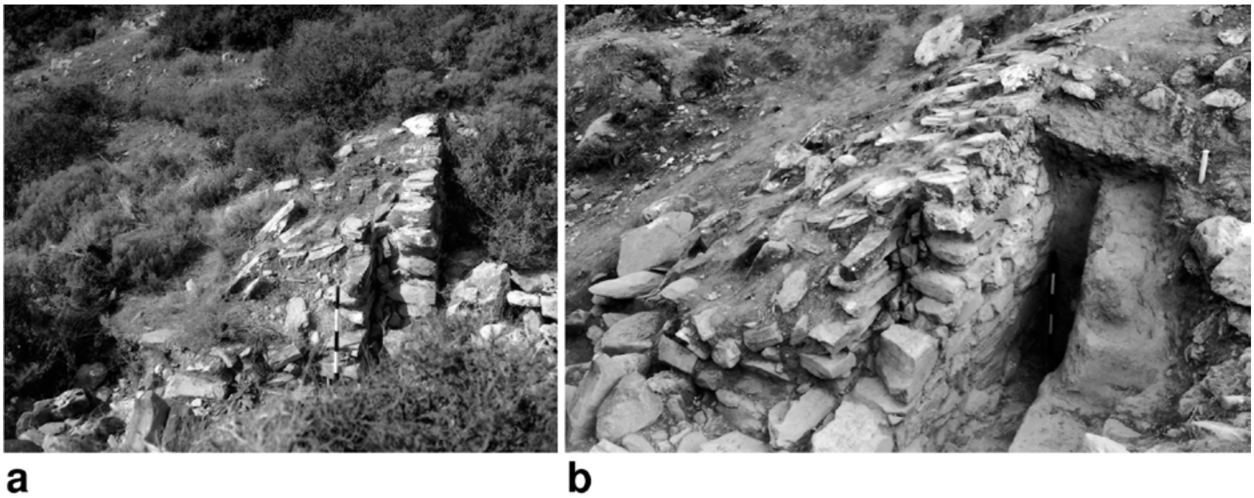

Fig. 11 – Views of Dam M9 before (a) and during (b) excavation. – (after Betancourt 2012: 31–32, figs. 18, 20).

Fig. 12 – Water-management system in Dune Creek Ravine, including Dam M9 at the centre and several check-dams. – (after Betancourt 2012: 26, fig. 13).

Each dam was constructed as a parallel pair of stone walls extending all the way across the ravine, with the space between the walls filled with packed earth and smaller stones (Fig. 11). All the stones were local. Part of the double wall was preserved only at one of the ends of Dam M9. This type of construction resulted in an extremely solid pair of dams across two ravines. Dam M9 was 3.62m high, 3.00m wide, and 15.5m long (Betancourt 2012: 27–28). Dam M29 was preserved 3.70m high, 3.10m wide, and 11.85m long (Betancourt 2012: 36–40). The tops of the dams were finished with flat stone slabs to prevent erosion (Betancourt 2012: 33, fig. 22). During the spring rainy season, the finished constructions would surely have held water for several weeks, to make it available both for human and animal consumption as well as for carrying it to the crops that had just been planted.

The dams, however, were just one part of the water-system on the island. The plan of the best preserved of the two ravine systems includes features both uphill and downhill from the dam (Fig. 12; Betancourt 2012: 26, fig. 13). Dam M9 is located toward the centre of the length of the ravine, and small check-dams are located both uphill and downhill from the dam. The water flowed from 79 meters above sea level down to sea level. In addition to the large Dam M9, the various small and low check dams would have slowed the water flow and preserved a small amount of water behind each wall. These check dams were easy to build, but they were so flimsy in construction that the surviving traces almost certainly suggest that many others were present originally. In addition to slowing the flow of the water, they would have blocked its passage enough to save a small amount just uphill from each low wall. Presumably these rather informal check dams each would have saved a small amount of rainfall that would have been useful to the nearby agricultural plots, and it could have been dipped out easily by a nearby land owner for their recent plantings on adjacent land. The surviving evidence suggests both a large communal effort to save a large quantity of water behind the two large dams and a more informal effort to add a little extra water conservation for individual crops.

The successful result of the water-management system can be measured by the fact that this off-shore island was not abandoned until well after the time when the dams were built (in Late Minoan IIIB, which would be about 1250 BC; Betancourt 2005: 295). The growth of the population during the Bronze Age is clearly demonstrated by the survey of the island (Betancourt *et al.* 2005: figs. 2–6). The challenge of feeding the people and animals residing on the island as the climate grew drier resulting in the loss of sufficient rainfall for successful agriculture was met by the implementation of a dam-construction system of considerable sophistication. In addition to the two large dams, the Minoan residents added a terrace wall on the uphill side of Dam 29 to prevent erosion from filling the water catchment basin from the soil at this location, a feature that was only added where it was needed because of the absence of bedrock at this point in the topography (Betancourt 2012: 44–47, figs 30–32). The system also included the encouragement of small check dams that added to the amount of conserved water and also provided new soil to replenish what gradually eroded away from the nearby terraces.

The source of an earlier development of such a sophisticated system is not readily apparent. Middle Minoan antecedents of this type in Crete have not been excavated, and it is possible that the earlier history of the use of double walls as dams is to be sought elsewhere. The system is more specialized than the use of earth dams, as was the case in Egypt. It was well suited to the rocky topography of the small Aegean island. Since the system was discovered at Pseira, evidence for water management during the Late Bronze Age at other sites in Crete has been documented. At Choiromandres there is a related type of agricultural system using a series of dams (Vokotopoulos *et al.* 2014; see also Chryssoulaki 2011), and recently excavated stone-lined water conduits fed by a nearby ravine came to light in the Minoan settlement of Mochlos (Soles *et al.* 2023; see also Flood and Soles 2014). The people of Minoan Crete became adept at managing water in different ways to serve their various needs, especially as their population grew and the climate gradually became drier, thus increasing the value of fresh water.

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Los Millares – Water supply and water management of a Copper Age fortification in Andalusia

Anorte Elisabeth Jakowski

Thanks to the support of the Ministry of Culture and Historical Heritage of the Regional Government of Andalusia, the German Archaeological Institute (DAI), Madrid Department, and the German Research Foundation (DFG), it was possible to investigate the water supply of the Copper Age fortress of Los Millares in the southeast of the Iberian Peninsula using archaeometric methods. The aim of this present contribution is to provide an overview of the water demand and water management of this settlement. First, the water supply system of Los Millares is briefly presented. Based on this, a water management balance is calculated. The focus of the considerations is the question of how many inhabitants in Los Millares could be supplied with drinking and process water and which management problems of the water supply had to be solved in times of crisis.

Keywords: Copper Age, Los Millares, population density, water management, water supply

Grâce au soutien du ministère de la Culture et du Patrimoine historique du gouvernement régional d'Andalousie, de l'Institut archéologique allemand (DAI) de Madrid, et de la Fondation allemande pour la recherche (DFG), il a été possible d'étudier l'approvisionnement en eau de la forteresse du Chalcolitique ancien de Los Millares dans le sud-est de la péninsule Ibérique utilisant des méthodes archéométriques. L'objectif de cette contribution est de donner un aperçu de la demande et de la gestion en eau de cet habitat. Tout d'abord, le système d'approvisionnement en eau de Los Millares est brièvement présenté. Sur cette base, un bilan de gestion de l'eau est, ensuite, calculé. Au centre des réflexions se trouve la question de savoir combien d'habitants de Los Millares pouvaient être approvisionnés en eau potable et en eau pour d'autres usages, et quels problèmes de gestion de l'approvisionnement en eau devaient être résolus en temps de crise.

Mots clés : Chalcolithique, Los Millares, densité de population, gestion de l'eau, approvisionnement en eau

Endülüs Bölgesel Hükümeti Kültür ve Tarihi Miras Bakanlığı, Alman Arkeoloji Enstitüsü (DAI), Madrid Departmanı ve Alman Araştırma Vakfı'nın (DFG) desteği sayesinde, İber Yarımadası'nın güneydoğusundaki Bakır Çağı kalesi Los Millares'in su kaynağını arkeometrik yöntemler kullanarak araştırmak mümkün olmuştur. Bu mevcut katkının amacı, bu yerleşimin su talebi ve su yönetimine genel bir bakış sağlamaktır. Öncelikle, Los Millares'in su tedarik sistemi kısaca tanıtılmaktadır. Buna dayanarak bir su yönetimi dengesi hesaplanmıştır. Değerlendirmelerin odak noktası, Los Millares'te yaşayan kaç kişiye içme ve kullanma suyu sağlanabileceği ve kriz zamanlarında su temini ile ilgili hangi yönetim sorunlarının çözülmesi gerektiği sorusudur.

Anahtar Kelimeler: Bakır Çağı, Los Millares, nüfus yoğunluğu, su yönetimi, su temini

Introduction

Los Millares is one of the largest Copper Age stone fortifications on the Iberian Peninsula. It was discovered in 1891 by two Belgian mining engineers, L. and H. Siret. The archaeological site is located 15km north of Almería on the right side of the Río Andarax, which flows there at about 190m asl. The approx. 5ha-large settlement was built on the Llano de Millares at about 260m asl. In the Copper Age, the height difference between the settlement and the river was even greater.

The Llano de Millares is limited by the Río Andarax in the north. Further boundaries are a small canyon in the west, the Rambla de Huéchar in the east and the heights of La Merina in the south (Fig. 1, map insert). The settlement itself consists of four areas located one behind the other, each separated and protected by a fortification wall to the west (Fig. 1, site plan). Due to the morphological conditions, no wall was needed in the other directions. The area of the innermost and oldest of the four fortification walls is additionally protected by a natural ditch. This settlement area is called Ciudadela. Outside the settlement on the Llano de Millares there exists a 13ha-large necropolis with approximately 80 tholoi, as well as 13 small outposts known so far on the surrounding heights.

Since archaeological research so far has focused mainly on the fortifications, but little is known about the interior of the four lines of fortification – building density, size of the huts, etc. – experts' opinions about the number of inhabitants of Los Millares differ widely:

> L. Siret notes a size of 5ha for the settlement of Los Millares, assuming that the actually inhabited area was about 2ha. In his opinion, only the citadel was extremely densely populated, while in the rest

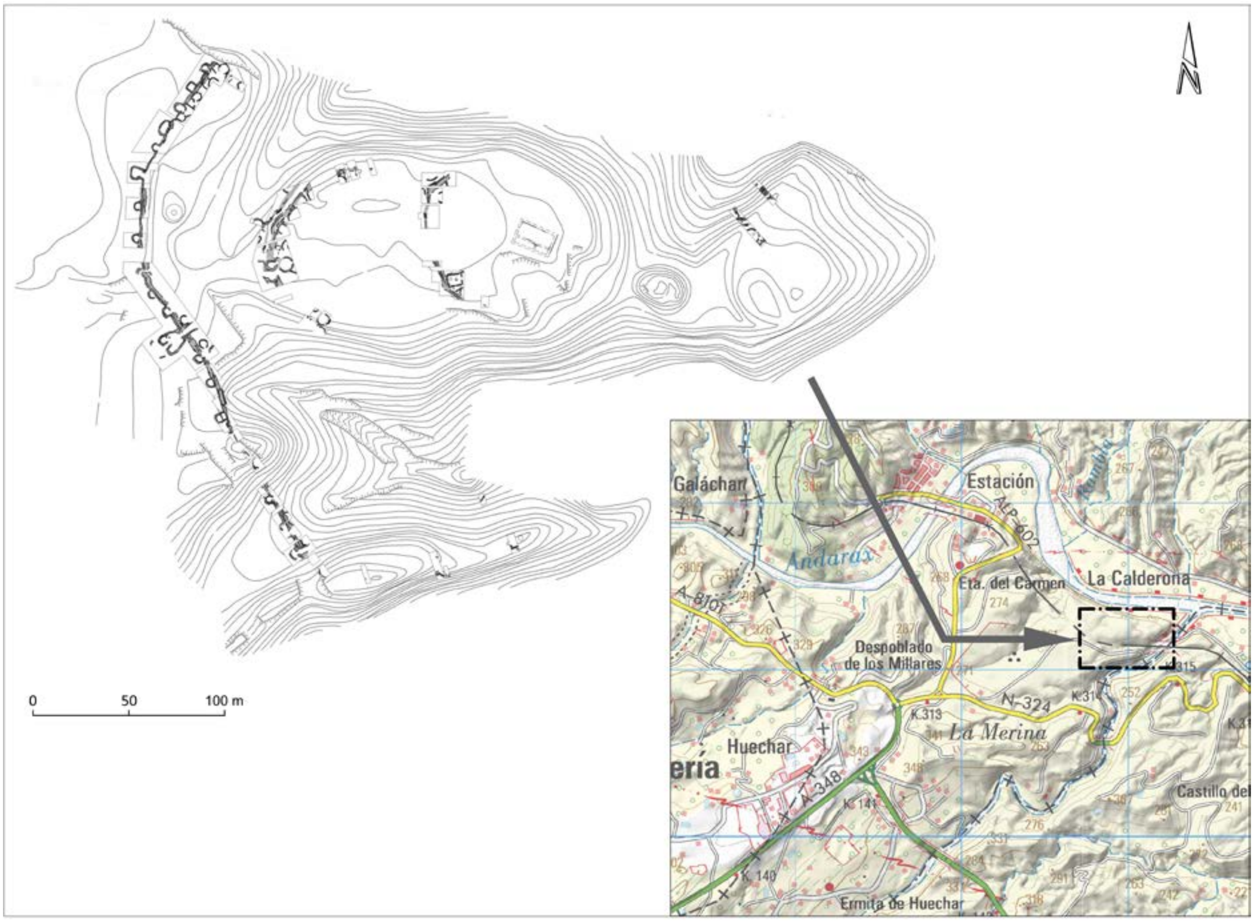

Fig. 1 – Site plan of the Copper Age fortification of Los Millares; map insert: topographical overview. – (Plan: F. Molina González; map insert: Instituto Geográfico Nacional de España, access 03/28/2023).

of the fortification there were groups and rows of houses and a lot of free space (Siret 1893; see Siret and Siret 1999: 196).

R. Chapman (1990: 153) also notes 5ha for the settlement area of Los Millares. However, he does not distinguish between more or less build-up areas. He derives the assumed population density of Los Millares and other Copper Age settlements from Ph. Kalb's study of the Copper Age settlement on the Cerro de la Virgen in Orce (Chapman 1990: 155–159; Kalb 1969a; Kalb 1969b). The round huts excavated there, ranging in diameter from <1m to 4m, allow him to conclude a maximum hut density of 1 per 100sqm settlement area, although we do not know whether this building density applies to the entire settlement — of Orce and also of Los Millares. In El Argar times the hut density even increased, but in the Later Bronze Age it decreased again (Chapman 1990, 156–157) To take these changes into account, R. Chapman, following C. Renfrew, estimates for the Copper Age in Iberia a population density of 200 inhabitants per hectare (Chapman 1990: 157). C. Renfrew (2011: 251) in turn refers to H. Frankfort (1950: 103) and assumes that his estimate of 400 persons per hectare in Mesopotamian cities is too high for Bronze Age cities in the Aegean because of the lower population density. He therefore assumes 300 persons per hectare for the Bronze Age and 200 persons per hectare for the Neolithic in the Aegean. To obtain the total population of Los Millares, the number of inhabitants per hectare must be multiplied by the settlement area. Thus, R. Chapman (1990: 152 table 14) calculates a population of 1000 people for Los Millares.

R. Risch (2013: 169) also gives a population of 75 to 140 people per hectare for the Iberian Copper Age, regardless if dealing with fortified or unfortified settlements or settlements enclosed by ditches.

L. Ruano Posada (2014: 15) even gives 1000 to 1500 inhabitants for Los Millares.

Since such a high number of inhabitants has not yet been proven in any way by finds within the settlement of Los Millares, M. Kunst, based on his excavations within the Copper Age fortification of Zambujal in Portugal, strongly doubts such assumptions (Kunst 2013: 197) and assumes a rather low building density for Los Millares.

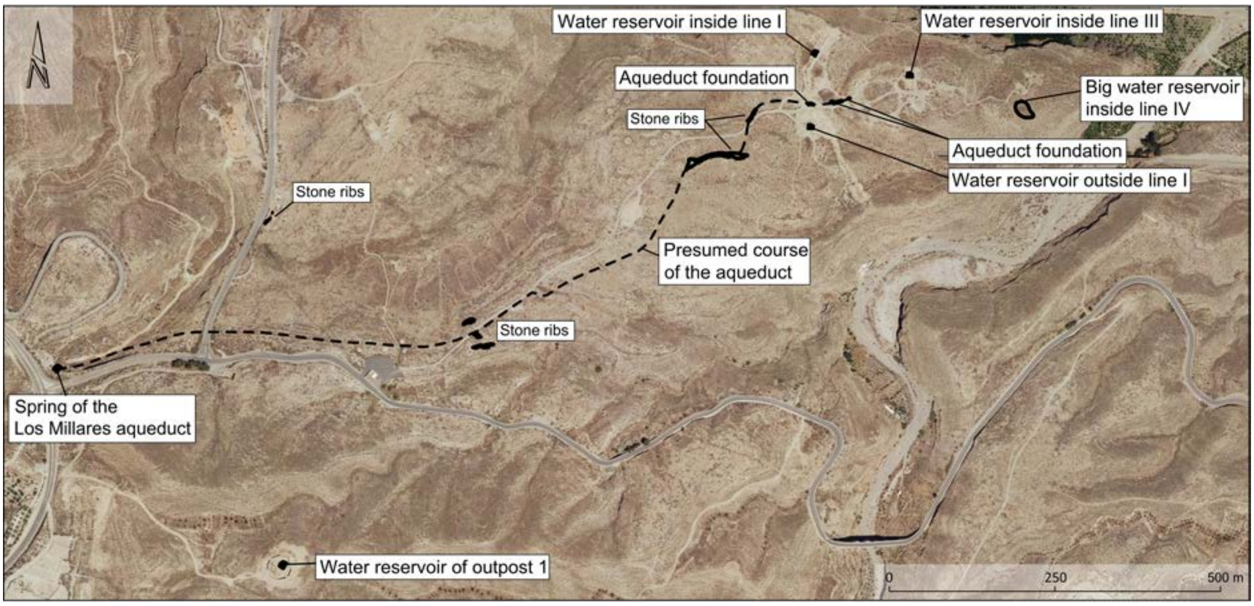

Fig. 2 – Water supply system of Los Millares, aerial view. – (Image source: Instituto Geográfico Nacional de España, access 11/06/2017).

Since there are so many different opinions about the population size of Los Millares, and no major excavations are currently planned within the settlement, no additional information will be obtained using archaeological methods in the near future. Therefore, a different approach to the question of population size makes sense. This fortified settlement, perched on a spur overlooking the valley of the Río Andarax in a perfectly defensible position, would not have been able to protect its inhabitants for more than a millennium if the drinking water supply had not been secured during that time. The intention of this study is therefore to determine how many people could be supplied with water within the fortification in the Copper Age and to approximate the possible population density in this way.

Water supply

Before discussing the water management of Los Millares in the Copper Age, the currently known water supply system will be presented (Fig. 2). Based on this, water management balance for the fortification can be calculated.

Already L. Siret (1892 and 1893; see Siret and Siret 1999: 164, 196–197) described the water supply of Los Millares: a spring that had already dried up at his time, a water conduit to the settlement and a large water reservoir within the settlement. These findings have recently be checked, adjusted and supplemented using archaeometric methods. The results of the archaeological, geological and hydrogeological investigations are described in detail in Jakowski (2021) and Jakowski *et al.* (2021).

The archaeological findings concerning water storage[1]

Four water reservoirs are known within or in the immediate surrounding of the fortification. Outside the outer fortification wall – on the left, just in front of the main gate – there existed a water reservoir which was probably used as a drinking trough for livestock (Martínez Fernández and Afonso Marrero 2003: 97; Molina González and Cámara Serrano 2005: 40). In Bastion VIII of the outer fortification wall, a 3m deep bell-shaped storage pit was excavated, 2m wide at base and 0.8m wide at top. It was covered with a slab of slate. As its walls were covered with a thick clay layer, it is interpreted as a water reservoir (Arribas *et al.* 1981: 95).

In the area of the third fortification wall, a 2m deep silo or water reservoir with a diameter of around 4m at the bottom was excavated. It had been carved directly into the rock (Arribas *et al.* 1983: 131) and sealed with clayey material (pers. inf. F. Carrión Méndez).

Within the area enclosed by the innermost or fourth fortification wall there exists an oval depression approximately 47m long and 30m wide, which was already interpreted as a water reservoir by L. Siret (1892 and 1893, see Siret and Siret 1999: 164, 197). However, the current investigations could not yet provide any evidence that this was a water reservoir in the Copper Age. Assuming that it was indeed a water reservoir, the overflow in the southeast, clearly visible in Figure 3, would have been very useful if water had constantly flowed through the settlement. If the maximum water level is set at the level of its overflow,

[1] For photos see Jakowski 2021: 159–160.

the volume today is approx. 270m^3. Originally the depression was probably even deeper, since the bottom is now covered by rock debris.

The archaeological findings concerning water transport[2]

At the outermost wall there is a quarter-circular foundation from which two straight rows of stones lead – diagonally to the wall – into the settlement. They were excavated in 1985 by A. Arribas and F. Molina and it is assumed that this may have been the entrance of the aqueduct into the fortification (Arribas *et al.* 1987: 250–251).

Between the outer and the second wall exists a strongly sintered rest of a wall foundation, running perpendicular to the fortification walls, which is already shown in the maps of L. Siret (1893, see Siret and Siret 1999: 197 fig. 168; Almagro Basch and Arribas Palau 1963: 19 fig. 3). There we found more than 50 calcium carbonate deposits of different sizes, which are caused by precipitation from running or dripping water. These sinter deposits may have precipitated in the Copper Age, but they may also be very much older or very much later. However, thorium/uranium analyses on these calcium carbonate deposits provided clear evidence of a leaky aqueduct, from which water flowed, or at least steadily dripped, in the Early and Middle Copper Age (Jakowski *et al.* 2021). Afterwards, the aqueduct was relocated and probably better sealed. This is proven by the excavations from 1953–1958. At that time section No. 3 ran parallel to the aforementioned sintered remains and continued towards the second fortification wall. There, too, sintered parts of the aqueduct were excavated (Arribas *et al.* 1987: 251). However, these had been covered by Copper Age hut walls (today, this section is backfilled).

Outside the fortress, L. Siret had identified four other parts of the aqueduct. Three of these are stone ribs about 30–90m long and 2–12m wide, over which the aqueduct may have passed. However, a verification is not possible today, since calcareous sinters or other indications of the aqueduct could not be found during our survey. At the fourth part, L. Siret suspected the aqueduct and the spring. But even there, no references to the aqueduct can be found today. From a hydrogeological point of view, a Copper Age spring is unlikely in this location.

[2] For photos and figures see Jakowski 2021: 155–158 and Jakowski *et al.* 2021: 262, 264–266.

The hydrogeological findings concerning water discharge[3]

According to the current hydrogeological survey, the spring that fed the aqueduct of Los Millares was located at the upper end of the canyon bordering the Llano de Millares to the west. Calcareous sinters at this site 1.25km west-southwest from Los Millares date from the end of the Copper Age respectively from the beginning of the Bronze Age. The original outlet of the spring is believed to be a few metres west of the investigated site, but is no longer accessible due to modern road and bridge constructions.

Although there is evidence that water was still flowing at this site when or shortly after Los Millares was abandoned, this does not necessarily mean that the water feeding the aqueduct must have come from there. Therefore, further results were provided by uranium and strontium isotope analyses, which allow conclusions about the catchment area of the water from which the calcareous sinters precipitated. Due to the similar strontium isotope ratios from the canyon and the aqueduct, it can be assumed that water from there fed the aqueduct of Los Millares. Since the strontium isotope ratios of the sinters are between those of the Quaternary recharge waters and the thermal water in the catchment area, the spring must have poured a mixture of thermal and near-surface groundwater.[4]

Because of this thermal water content, it can be assumed that the spring that fed the aqueduct of Los Millares was an evenly pouring spring. This is because the young groundwaters near the surface are strongly influenced by seasonal fluctuations, while the older thermal waters flow much more steadily and do not react as quickly to climate changes.

The fact that the aqueduct was leaking for a really long period of 750 years shows that it must have been a strongly pouring spring. It was not necessary to ensure that the aqueduct was tight. There was no need to save water.

Since water was still flowing in the canyon at the beginning of the Bronze Age, although the effects of the 4.2ka cal BP event led to the drying up of most springs in La Mancha (Benítez de Lugo and Mejías Moreno 2014: 69), about 150–300km north of Los Millares, it seems that ultimately other reasons but not a lack of water led to the abandonment of Los Millares.

[3] About the discovery of the Copper Age spring's location and for photos see Jakowski 2021: 166–170 and Jakowski *et al.* 2021: 273, 276–278.

[4] The use of thermal water as drinking and service water is not uncommon. The modern water supply of Alhama de Almería, 5km west of Los Millares, is based on a deep well that provides groundwater at a temperature of 28.9° C.

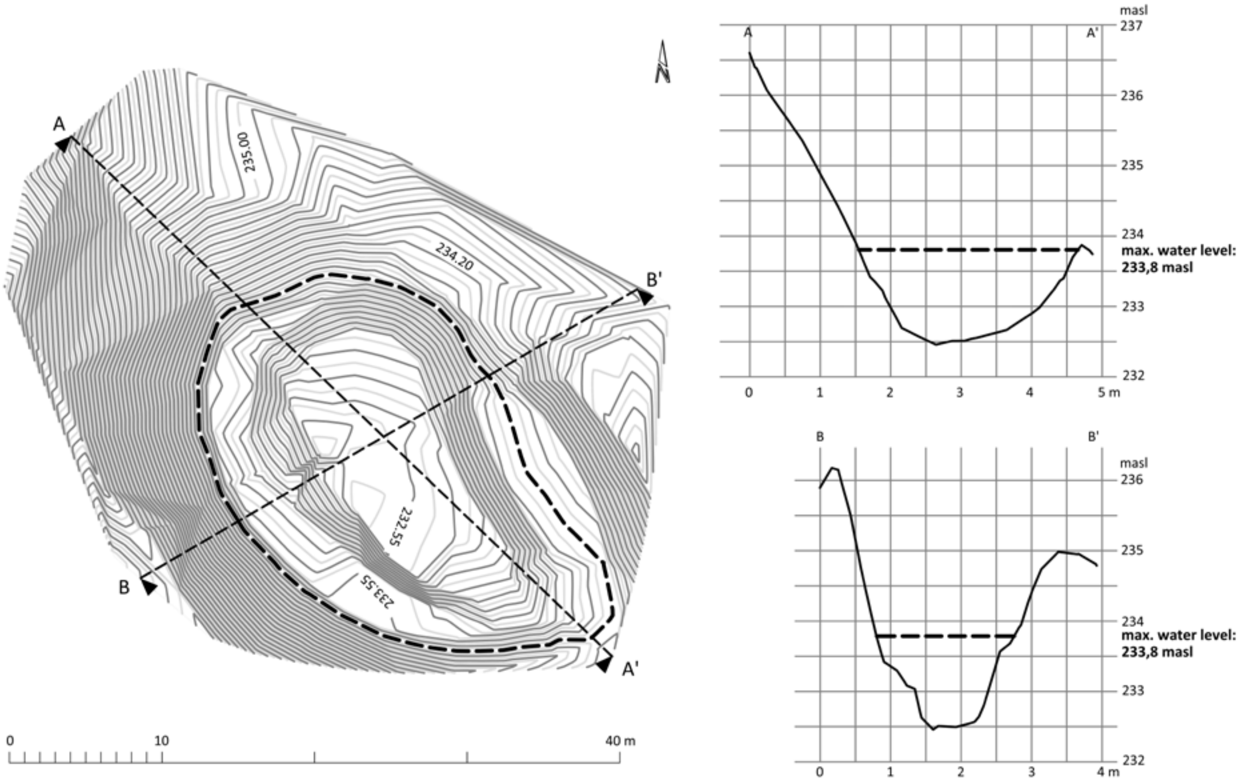

Fig. 3 – Presumed water reservoir inside line IV. Plan and profiles.
(Archaeological interpretation: A. Jakowski; survey and drawing: D. Schäffler).

Description of water supply system

Based on these archaeological findings the water supply system of Los Millares can be envisaged as follows: From the spring located 1.25km west-southwest of the fortification the water was transported to the settlement via the aqueduct. Inside, it was probably distributed to various delivery points and water reservoirs via an as yet unknown channel system. At the aforementioned large reservoir (Fig. 3) at the lowest point within the area enclosed by the innermost fortification wall, unused water probably overflowed into the Rambla de Huéchar. Perhaps the water supply was interrupted due to lack of demand within the settlement, and was diverted outside for field irrigation and livestock farming. But so far there is no archaeological evidence of either overflow or field irrigation.

Water management

From a hydrogeological point of view, digging a well within or near the settlement was not expedient in the Copper Age and would not be today (Jakowski *et al.* 2021). Thus, on the one hand, the total water demand of the inhabitants of Los Millares probably had to be met by the aforementioned and perhaps other, still unknown springs that existed there in the Copper Age. On the other hand, sufficiently large water reservoirs within the settlement had to ensure the water supply in case of a crisis.

The following water management considerations must be examined very critically, as they are associated with a large number of unknowns and imponderables. First, the water demand of the population of Los Millares has to be determined. Therefore, we must consider how many people lived in Los Millares simultaneously. To estimate this, in turn we need two other parameters: settlement area and population density.

Settlement area

The area enclosed by the innermost or fourth fortification wall, the so-called citadel, has a size of 0.4ha. The area enclosed by the third wall is 0.5ha, that between the second and third walls is 0.8ha, and that between the outer or first and second walls is 2.9ha. In total, the maximum settlement area is 4.6ha.

Population density

In the absence of well-founded data, the following calculations are based on the assumptions of R. Chapman. A population of 200 inhabitants per hectare is assumed for the following water requirement calculation, although, as described above, this number

has not yet been substantiated in any way by findings within the settlement. Nevertheless, it is common practice to consider the "worst case" for the supply security of a settlement, i.e. the maximum water demand, when calculating a water management balance.

These calculations, assuming 200 residents per hectare and 4,6 hectares, yield a population of 920 residents, rounded down to 900 residents for Los Millares.

Water demand

The water demand of a settlement depends on the needs of the inhabitants, craft – copper metalworking among others – trade and agriculture (for livestock and field irrigation). In Los Millares there has been some specialization of craftsmanship, because within the settlement of Los Millares copper was processed in various places.

No statement can be made about livestock within the fortification as long as we do not have any information about the building density. It is quite possible that animals were kept in a part of the area enclosed by the fortification, for example between the outer and the second fortification wall. Then the aforementioned population of 900 inhabitants would be an overestimate.

F. Klimscha *et al.* (2012: 130) set a water requirement for human consumption of 10 litres per inhabitant per day for the Late Copper Age/Early Bronze Age settlement of Tall Hujarat al-Ghuzlan in Jordania, based on the water consumption for the water supply of Pergamon determined by G. Garbrecht (2001: 38). The latter gives a water requirement for Pergamon 'under … warlike emergency conditions' of 7 litres per inhabitant per day 'for drinking/cooking and for the most necessary hygiene' in winter and 13 litres per inhabitant per day in summer.

For crafts and trade F. Klimscha *et al.* (2012: 130) give also an unspecified, 'estimated' water demand of 10 litres per inhabitant and day.

In addition, water must be kept available for livestock inside or outside the settlement. According to DVGW (2008: 16), the water demand of a livestock unit is 50l/d, with one livestock unit corresponding to 1 cattle, 3.3 pigs or 10 sheep/goats (DVGW 2008: 28). Based on a survey by the FAO (2006) in 21 African states in 2005/06, Klimscha *et al.* (2012: 131) assume 0.31 cattle and 0.54 sheep/goats per inhabitant.

However, F. Molina González and J. A. Cámara Serrano (2005: 87) have demonstrated percentages of 53.4–62.4% goat, 22.1–29.6% pig, 10.4–17.9% cattle, and 5.1–8.3% rabbit, based on the animal bones found in the various settlement areas of Los Millares. In contrast to pigs, cattle play a minor role at the site. Taking into account the animal percentages according to F. Molina González and J. A. Cámara Serrano, instead of 0.31 cattle and 0.54 goats/sheep per inhabitant, we assume 0.1 cattle with a daily water demand of 50 litres per cattle, 0.21 pigs with a daily water demand of 16 litres per pig and 0.54 goats with a daily water demand of 5 litres per goat per inhabitant. Thus, about 11 litres per day and inhabitant would have been required for livestock in Los Millares.

To what extent field irrigation should also be taken into account cannot be clarified based on the current state of research. According to L. Ruano Posada (2014: 23), A. Gilman and J. B. Thornes (1984: 114–118) assume that the aqueduct was an irrigation canal, while R. Chapman (1991: 170–195) assumes rain-fed agriculture.

For 900 inhabitants with a water demand of 31l/d (10l/d for human consumption, 10l/d for crafts, and 11l/d for livestock), the average daily water demand for Los Millares would then have totalled 28cbm/d. Because the need of water, especially for agriculture including livestock, is not evenly distributed throughout the day, for a worst-case scenario an hourly peak factor of 7.6 is applied (DVGW 2008: 16). Thus, a maximum of *c.* 9m^3/h was required, which corresponds to a spring discharge of approximately 2.5l/s.

Water management balance

The maximum spring discharge needed to supply 900 persons in Los Millares and their livestock outside Los Millares was approximately 2.5l/s. According to the hydrogeological results presented above, the Copper Age spring west of Los Millares could provide this amount of water.

Storage capacity in case of a crisis

Now we compare the water demand with the storage capacity in case of a crisis – if the settlement was cut off from fresh water supply.[5] The water reservoirs known so far within the settlement have volumes of about 10m^3 (within the area enclosed by the first fortification wall and within Fortín 1), of 30m^3 (within the area enclosed by the third fortification wall) and the largest of at least 270m^3 (within the citadel, the oldest part of Los Millares) – if we assume that it really was a water reservoir.

[5] According to friendly personal communication from Fernando Molina González, University of Granada, on 11/23/2018, larger quantities of arrowheads have been found so far only outside the outermost fortification wall. It can therefore be assumed that major attacks took place in the time of the maximum expansion of the fortification in the Middle Copper Age.

If the water reservoirs so far suspected within the settlement, with a total volume of 310m^3, served as the only water reserves for 900 people, with a minimum water demand for human consumption of 10l/d, the stored water would have been sufficient for about one month.

The previous calculations show that even with a high population density, the water supply of Los Millares was more than guaranteed in the event of a crisis by the existing storage facilities within the settlement. Fresh water supply in the event of a crisis was the greater problem. Since there were probably no wells but only water reservoirs, their refilling had to be ensured in order to prevent bacterial contamination of the water. Rapid bacterial contamination of the water on the way from the spring to the consumers was not to be feared due to the increased temperature, since the germs responsible for contamination usually avoid elevated temperatures. But if the water was not used for a longer time, it would definitely have become contaminated.

Thus, L. Ruano Posada's assumption that the 13 known outposts of Los Millares served not only to defend against attackers but also to protect the aqueduct (Ruan Posada 2014: 16) seems more than justified.

Conclusions

The water supply system of Los Millares was fed by a steady and strongly pouring spring located 1.25km west-southwest of the fortification. The water was transported to the settlement via an aqueduct. Inside, it was probably distributed to various delivery points and water reservoirs via an as yet unknown system of channels. At the lowest point within the area enclosed by the innermost fortification wall, unused water probably overflowed into the Rambla de Huéchar.

In the pre-Roman period of the Iberian Peninsula, this complex system is unique in its temporal and spatial dimensions. There is no other example of a water supply consisting of water discharge, water transport for more than one kilometre and water storage.

With the help of the calculations described above, it could be shown that the aqueduct of Los Millares was able to ensure the water supply of the settlement for a period of at least 750 years, even for 900 inhabitants without direct access to drinking water. Today, this is a major challenge – especially because of the extremely long period of use for which modern water supply systems are not designed. At the end of the 4th millennium BC it was efficiently mastered.

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The Motilla culture: a hydraulic culture facing the challenge of the 4.2 ka cal BP climate event

Luis Benítez de Lugo Enrich and Miguel Mejías Moreno

The *motilla* is a type of Chalcolithic and Bronze Age settlement in La Mancha (Spain). *Motillas* may have constituted the most ancient groundwater collection systems in Europe. They were built during the 4.2ka cal BP climatic event, in a time of environmental stress after a period of severe and prolonged drought. In these environmental conditions, the construction of these wells was a successful solution that lived on for nearly a millennium and played a major part in the processes of change towards a more complex and hierarchical society. This paper presents the advances made over the last decade on paleoecological, hydrogeological, geophysical, archaeoastronomical, anthropological, archaeogenetic and archaeological aspects of the Motilla culture.

Keywords: Climate change, Prehistoric Archaeology, Spain, Bronze Age, groundwater management

La *motilla* est un type d'habitat du Chalcolithique et de l'âge du Bronze à La Mancha (Espagne). Les *motillas* constituent peut-être les systèmes de collecte d'eau souterraine les plus anciens d'Europe. Ils ont été construits lors de l'événement climatique de 4,2 ka cal BP, dans une période de stress environnemental après une période de sécheresse grave et prolongée. Dans ces conditions environnementales, la construction de ces puits a été une solution réussie qui a perduré pendant près d'un millénaire et a joué un rôle majeur dans les processus de changement vers une société plus complexe et hiérarchisée. Cet article présente les progrès réalisés au cours de la dernière décennie sur les aspects paléoécologiques, hydrogéologiques, géophysiques, archéoastronomiques, anthropologiques, archéogénétiques et archéologiques de la culture des *motillas*.

Mots-clés : Changement climatique, archéologie préhistorique, Espagne, âge du Bronze, gestion des eaux souterraines

Motilla, La Mancha'da (İspanya) Kalkolitik ve Tunç Çağı'na ait bir yerleşim türüdür. Motillalı'lar Avrupa'daki en eski yeraltı suyu toplama sistemlerini oluşturmuş olabilir. Bunlar, cal. MÖ 4.2ka iklim olayı sırasında, şiddetli ve uzun süreli bir kuraklık döneminin ardından, çevresel stresin yaşandığı bir dönemde inşa edilmişlerdir. Bu çevresel koşullarda, bu kuyuların inşası, yaklaşık bin yıl boyunca yaşayan başarılı bir çözüm olmuş ve daha karmaşık ve hiyerarşik bir topluma doğru değişim süreçlerinde önemli bir rol oynamıştır. Bu makale Motilla kültürünün paleoekolojik, hidrojeolojik, jeofiziksel, arkeoastronomik, antropolojik, arkeogenetik ve arkeolojik yönleri üzerine son on yılda kaydedilen gelişmeleri sunmaktadır.

Anahtar Kelimeler: İklim değişikliği, Tarih Öncesi Arkeoloji, İspanya, Tunç Çağı, yeraltı suyu yönetimi

Introduction

La Mancha is a natural region of the southern plateau of the Iberian Peninsula, west of the Mediterranean (Fig. 1). It comprises part of the provinces of Ciudad Real, Albacete, Cuenca and Toledo. It is delimited by the reliefs of the Sierra Morena to the south, the Montes de Toledo to the north and west, and the Serranía de Cuenca to the northeast. It is a basically a flat high plateau, with an altitude between 600 and 700m; the main river courses are the Guadiana, Záncara, Cigüela and Júcar.

During the Bronze Age, La Mancha was inhabited by one of the main cultural complexes of the Iberian Peninsula: the Motilla culture (Aranda *et al.* 2008; Benítez de Lugo Enrich and Mejías 2015; 2017); Martín Morales *et al.* 1993; Mejías *et al.* 2020; Sánchez Meseguer 1994). The name of this group comes from the type of archaeological site characteristic of the Bronze Age of La Mancha: the *motilla*. *Motillas* are archaeological sites characterized by irregular masonry enclosures made of limestone masonry and mud, with a circular floor plan and, in a few cases, a central tower. They were built on the southern plateau of Spain, in the Upper Guadiana Basin, where it was possible to access the water table of the aquifers with prehistoric technology (Fig. 2). The first inventory of these sites was presented in 2010 (Benítez de Lugo Enrich 2010); currently only 45 *motillas* are known (Mejías *et al.* 2020; Benítez de Lugo Enrich and Mejías 2022). This census is likely to increase owing to new discoveries, and the fact that this number reflects losses derived from plundering must be taken into account (Benítez de Lugo Enrich 2010; 2013; Ocaña 2007). Research on the Motilla culture has undergone substantial changes with respect to what was known only a few years ago (Benítez de Lugo Enrich 2024b). The following is an in-depth description of these advances, explained by areas of knowledge.

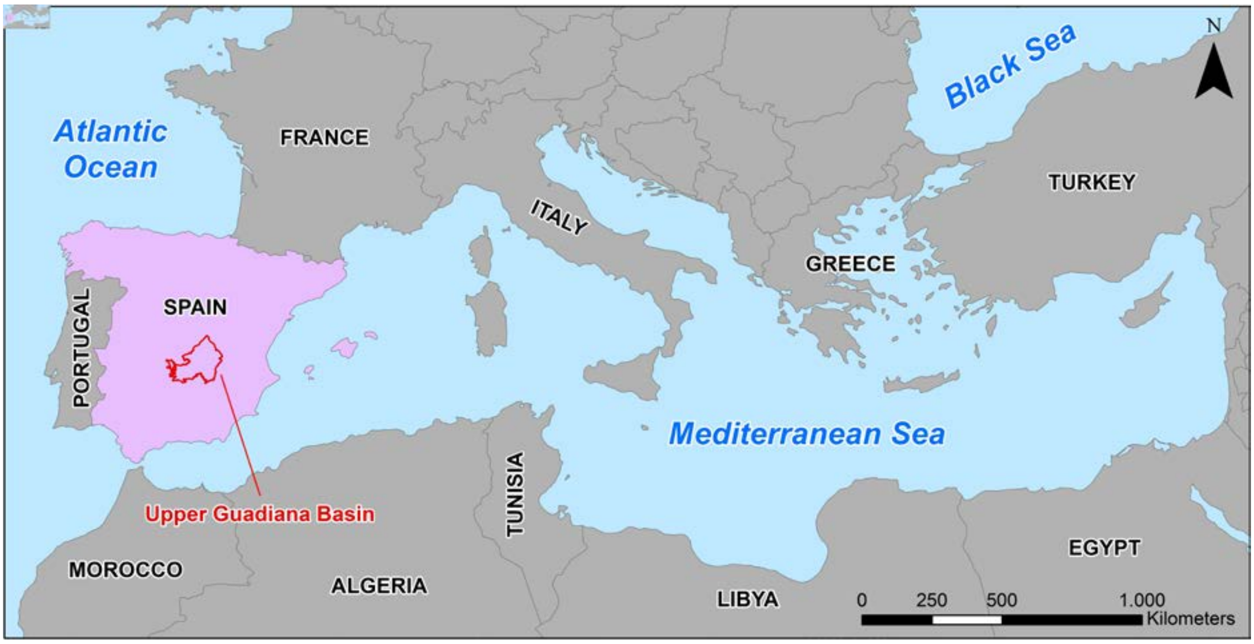

Fig. 1 – Location of the natural region of upper Guadiana river basin in the context of the Mediterranean Sea basin. – (Map: Authors' design).

Fig. 2 – Location of motillas on the synthetic hydrogeological map of the upper Guadiana river basin. – (Map: Authors' design).

Palaeoecology: influence of the 4.2ka cal BP climatic event on the origin of the Motilla culture

In La Mancha, research carried out by the Environmental Archaeology Research Group (Institute of History, CSIC, Madrid), at several sites of the Motilla culture, has clearly revealed the process of environmental stress at the end of the Chalcolithic period caused by climatic changes derived from the 4.2ka cal BP event. La Mancha is a territory with few perennial river courses. The entire Sierra Morena, and even the southern part of the province of Ciudad Real, drain into the Guadalquivir river basin, not into the Guadiana river basin. The Guadiana river, in its upper course, is fed mainly by discharges from the regional aquifer, at times when the rainfall regime and groundwater exploitation allow it. There are no mountains that store water in the form of snow, and the average rainfall is about 420mm/year, so the available water resources are mainly in the subsoil. The volume of water stored in the aquifers and its phreatic level have suffered a drastic decrease since the last third of the 20th century, due to its exploitation for different uses, and this continues to the present time.

The scarce archaeological data available on the communities that lived in La Mancha during the Chalcolithic reveal a territory of small villages located near watercourses, whose dead were deposited, in general, in collective burials, primary or secondary, and located in shelters or burial caves (Benítez de Lugo Enrich *et al.* 2003; 2019; Benítez de Lugo Enrich 2018a; 2018b). The beginning of the Bronze Age brought intense social changes to La Mancha. Around 2350 cal BC rainfall dropped drastically for several centuries, in an event that is well studied and described worldwide – the 4.2ka cal BP climatic event –, which in La Mancha has been verified in archaeological sites such as the motilla of El Azuer and Castillejo del Bonete (Terrinches) (López Sáez *et al.* 2014; 2017; Benítez de Lugo *et al.* 2014a; 2015a; Mejías *et al.* 2020). These findings are consistent with facts widely reported in the scientific literature, which describe how, at the end of the 3rd millennium cal BC, European, Near Eastern and Egyptian societies

MOTILLA DEL AZUER	Phase 0 (3000–2800 cal BC)	Phase I (2200–2000 cal BC)	Phase II (2000–1800 cal BC)	Phase III (1800–1600 cal BC)	Phase IV (1600–1350 cal BC)
Material culture	Chalcolithic	Bronze Age Bell Beaker pottery fragments	Bronze Age	Bronze Age	Bronze Age Cogotas I pottery fragments
Environment	Deforested landscape	Deforested landscape High water table	Disappearance of riparian forest	Deforested landscape	↑ Hygrophytes Riparian forest High water table Humid grasslands
Climate	Arid	Arid climate Arid and continental ↓↓ Precipitation	Maximum aridity Dry river	↑↑↑ Humidity ↑↑↑ Precipitation Warm climate	↑↑↑↑ Humidity ↓↓ Temperatures.
Structures	Hut bottoms, silos and dumps dug into the alluvial gravels	Pit, tower, rampart and masonry silos	Monumentalization of the pit Silos nested inside Ovens Constructions outside	Dismantling of silos Constructive remodeling	Disappearance of silos Clogging of the well converted into a cistern Cyclopean wall
Activity	Sporadic occupation	Start of permanent occupation. ↑↑↑↑ Anthropization	Intensive agriculture ↓ Breeding of ovicaprids, pigs and equids. Fires	Increased presence of bovids and equids	Outdoor habitation Motilla abandonment ↓ Anthropization ↑ Grazing

Fig. 3 – Activity in the Azuer motilla and its relationship with the climatic event 4.2ka cal BP. – (Authors' design: based on Nájera *et al.* 2012; López Sáez *et al.* 2014).

experienced large-scale political upheavals and social changes. The depopulation and abandonment of previous settlements, the cessation of long-distance exchange networks and routes, and the great political crises that brought about the end of the Akkadian Empire or the tensions in the Egyptian Old Kingdom, have been related to the onset of a great drought that lasted until approximately 1850 cal BC.

In the most studied *motilla*, the one located in the Azuer River, archaeologists have found evidence for its use for almost a millennium, with four major well-dated phases (Fig. 3) superimposed on a first occupation of Chalcolithic huts detected in the same place, 600 years before the beginning of the construction of the *motilla*. The construction of the tower, and its impressive well, have been dated precisely to the beginning of the climatic event to which we have referred. In its Phase II, between 2000 and 1800 cal BC, the inhabitants of La Mancha had to face the most extreme rigours of the aridity of the 4.2ka cal BP climatic event. Subsequently, during Phases III and IV, humidity levels recovered progressively until this *motilla* became uninhabited. Only in the last Phase IV (1600–1350 cal BC) has housing been reported in the outer spaces around the *motilla*, as a place of residence, according to its researchers. This is important: no settlement has been described around the *motilla* during its first centuries of existence.

After the return of the rains, the rivers and springs began to flow again. The *motillas*, installed in strategic locations in very specific environmental circumstances, lost their raison d'être and suffered the onslaught of surface runoff. The plinths of their walls, made of simple mud, eroded. Moisture rose by capillarity, disintegrating the walls. Their freshwater wells, installed in the riverbed, or very close to it, were flooded with muddy surface water, sometimes brackish. Around 1350 cal BC the Motilla culture disappeared, giving way to some poorly understood centuries during the Final Bronze Age, practically lacking in archaeological information, with some decontextualized exceptions (Montero Ruiz *et al.* 2002). Only well into the 1st millennium BC do we again detect an organized territory in the southern Meseta, around Iron Age *oppida*. This cultural collapse of the Final Bronze Age is not only limited to the Motilla culture; it is a phenomenon that can also be seen in the El Argar culture, in the south and east of the Iberian Peninsula. In short, in recent years we have advanced in the explanation of the origin of the Motilla culture thanks to the contribution of palaeoecology (Fig. 4).

Fig. 4 – Cultures of El Argar and of the motillas in Iberia. – (Drawing: Jaime Moraleda).

Hydrogeology and geophysics: explaining the spatial distribution of *motillas*

One question that has vexed researchers for decades is why the *motillas* are located where they are. Considerations of defence, transhumance or social organization have been proposed. Recently, several studies reveal a series of geological and hydrogeological data that turn out to be common to the different *motillas* and may be revealing a pattern about the construction and use of these enclaves (Benítez de Lugo Enrich and Mejías 2016, 2017; Mejías *et al.* 2014).

Their location near riverbeds initially ensured a water supply, either by proximity to the resource or by digging wells in dry periods when the surface water stopped flowing through the riverbeds and the river disappeared, leaving the shallow water table in the alluvium or below it. The observation of the geology near the *motillas* has revealed that the Pliocene limestones or the carbonate materials of the Jurassic and Cretaceous, which respectively form the upper and lower regional aquifers, constituted the objective to be achieved by the builders of the *motilla* wells to guarantee the water supply for the Bronze Age settlements of La Mancha. The *motillas* were built wherever the phreatic level of the regional aquifer could be reached with the available technology of the time. They were not necessarily in the riverbeds or in the middle of lagoons. There are *motillas* found in the middle of the La Mancha plain, as is the case of the Torralba *motilla*, from which groundwater could be accessed by simply digging a well about 5m deep (Benítez de Lugo Enrich *et al.* 2023a).

Given these new data, explanations for the choice of location of the *motillas* must necessarily be modified. These sites were not built in association with roads or droveways, as we have shown in previous works (Benítez de Lugo Enrich *et al.* 2022a; 2022b). Neither were they in strategic locations due to their defensive characteristics; they are often found in depressions, without visual control and dominated by surrounding hills, as in El Retamar (Benítez de Lugo Enrich *et al.* 2022) or El Acequión (Benítez de Lugo Enrich 2023). The latter was not built *on 'a small islet', nor should we 'imagine it always surrounded by water'* (Fernández-Posse *et al.* 1996: 118). Today we know that it was built when the lagoon had dried up and without visually dominating the surroundings from any promontory. The elevation is artificial; it is a tell formed by the ruin of the settlement itself, which was installed on the very bottom of the lagoon when it was dry. This was demonstrated in 2014 by competitive research with a

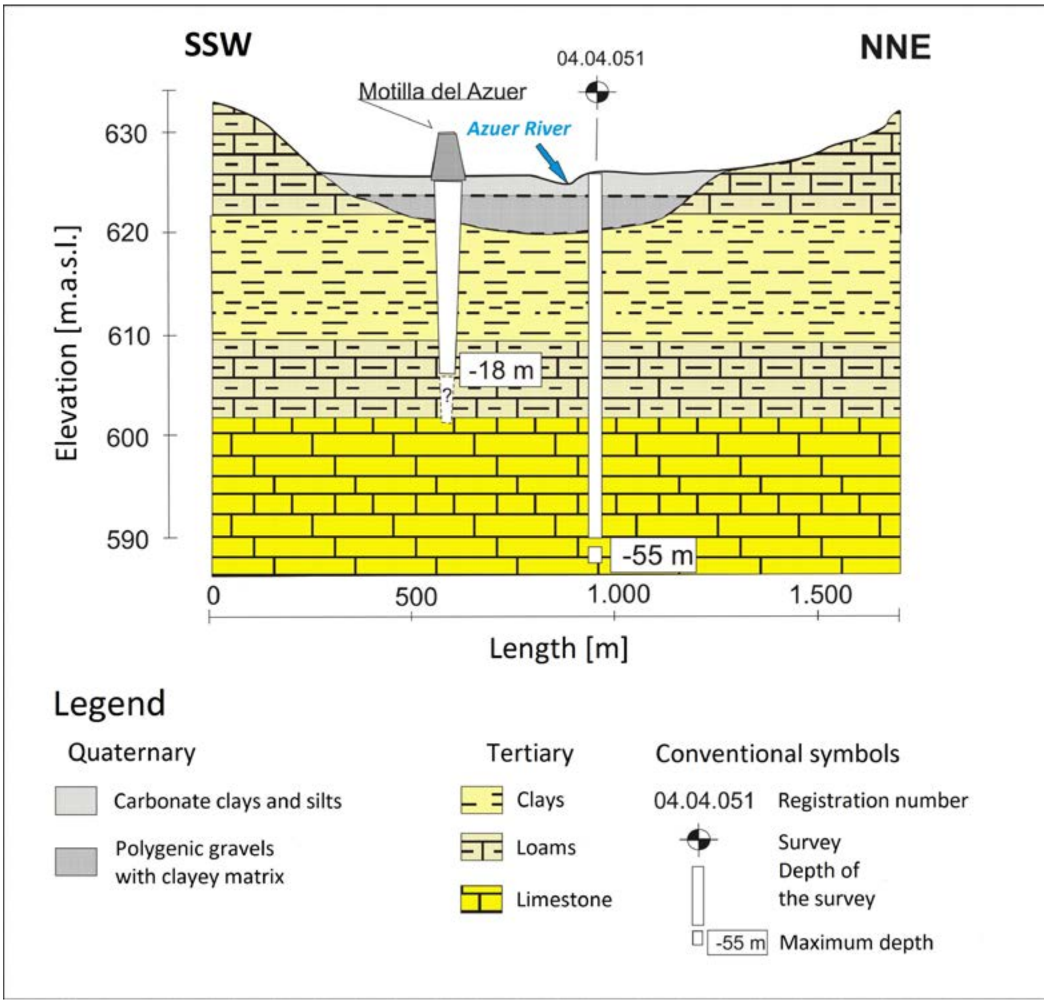

Fig. 5 – Transverse geological cross section of the river Azuer and its homonymous motilla. – (Drawing: Authors' design).

budget of 30,000€ promoted by the Junta de Comunidades de Castilla-La Mancha and the Geological and Mining Institute of Spain. The El Retamar *motilla* was not built in the middle of the Guadiana riverbed *because '(...) both when it carried water and when the riverbed was swampy, it was a barrier difficult to cross from the banks'* (Colmenarejo *et al.* 1987: 90).

Those who built the *motillas* did not seek to surround them with water for their defence, as was the objective in medieval castles. To imagine the landscape of La Mancha in the year 2000 BC as it is today is a presentist interpretation that leads to error. The wetlands of La Mancha, in addition to being completely unhealthy, and therefore unattractive for the installation of settlements in their interior, are difficult to cross. To build a settlement in the middle of an unhealthy and swampy marsh is difficult to understand, unless this environment was dry for a long time due to a climatic event.

The *motillas* may constitute the oldest hydraulic system in Europe designed to extract water from the subsoil (Fig. 5). The central tower detected in the *motilla* of El Azuer could have been used to extract and distribute water from the aquifer using the force of gravity; this was probably by means of a system similar to the *magrod* still used in areas of Ifni (Morocco). The archaeological evidence that such a construction would leave behind after its ruin would be, in part, similar to that of a *motilla* (Fig. 6).

In La Mancha there are still waterwheels raised above ground level in order to obtain pressure to irrigate their surroundings by gravity. The raised waterwheel is a groundwater extraction technique that may have its antecedents in the *motillas*. Around the *motillas*, limited areas of agriculture and livestock farming could have been developed on the fertile silt of the riverbanks and at times when water did not flow through the riverbed, thanks to the water extracted from the subsoil. These activities may have required the construction of small buildings around the *motilla*. Water channels and numerous horse remains found in the *motilla* of El Azuer seem to indicate the existence of something similar to irrigation ditches and horse breeding (Fig. 7).

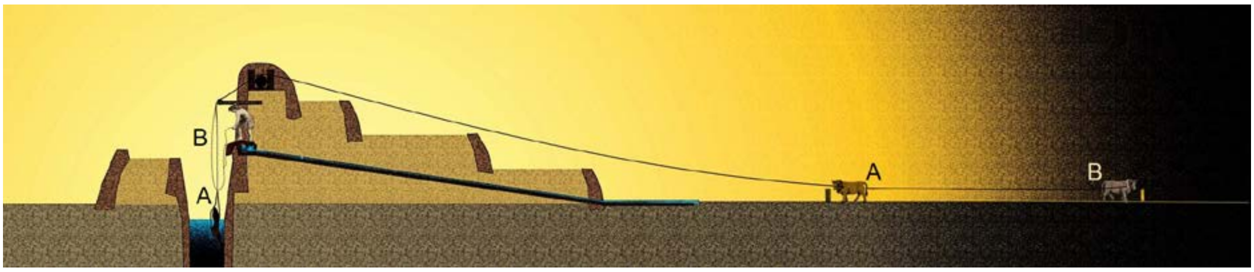

Fig. 6 – Graphic illustration of withdrawal and elevation of water (magrod) used in Ifni (Morocco). At position A, the draught animal is near the well and the goatskin bag is lowered into the water. At position B the animal pulls the bag to withdraw the water. The well at the motilla of Azuer might have been of this kind and would have been exploited in the same way. – (Drawing: Authors' design).

Fig. 7 – Aerial view of the motilla of Azuer (Daimiel, Ciudad Real) with water table at a high elevation, after a dry period, in 2013. – (Photo: Authors' photograph).

The Bronze Age Motilla culture of La Mancha can be considered the first hydraulic culture in Europe. After it, many centuries later, came aqueducts, *qanats* and other hydraulic solutions to capture and direct water. The existence of wells has only been confirmed by archaeological excavations in the *motilla* of El Azuer. However, by means of surface geophysical surveys, electrical resistivity readings compatible with clogged wells have been obtained in five other *motillas*: La Vega (Teixidó *et al.* 2013), El Cura, Santa María, El Retamar and El Acequión (Ibarra 2015). Consequently, the existence of wells reaching the water table of the regional aquifer inside these settlements seems to be a pattern of the Motilla culture.

To protect these freshwater wells from runoff caused by occasional floods or by the end of the 4.2ka cal BP climatic event, the powerful walls surrounding the *motillas* must have been built. These can be interpreted as fortification walls, but not every large wall has to have a defensive function. This is especially the case if they are not vertical, and of irregular masonry and accessible. Rather than viewing them in military terms, they can be interpreted as dikes, as the research team of the *motilla* of El Acequión pointed out in *1996: '(…) the external [wall] is built with a strong slope on the outside that functions as a dike against the waters of the lagoon'* (Fernández-Posse *et al.* 1996: 119). In short, we have also made progress in explaining the location of the

motillas thanks to the combination of other specialist disciplines, such as hydrogeology and geophysics.

Astrophysics and forensic anthropology: the discovery of a prehistoric solar cult

The ideological aspects of prehistoric cultures, such as religion or politics, are often more evanescent and less clear than those of an economic or social nature. In the last two decades, in addition to the advances already described, there has been another of singular interest that sheds light on the religious aspects of the Motilla culture, mainly from the prehistoric sacred site known today as Castillejo del Bonete (Benítez de Lugo Enrich *et al.* 2014a; 2014b; 2014c; 2015a; 2015b; 2020a; 2020b; 2020c). It is a unique enclave consisting of a funerary cave monumentalized by means of tumuli and corridors with solstitial orientations, at the sunrise and sunset of the winter and summer solstices, which create scenic plays of light and shadow.

Although in its external shape Castillejo del Bonete looks like a *motilla*, in 2014 we falsified our initial hypothesis that this site was a fortified access to the aquifer of the Campo de Montiel and demonstrated that there was no possible access with the means of the time to the water table (Benítez de Lugo Enrich *et al.* 2014a). The material culture found in Castillejo del Bonete is similar to that found in the *motillas*, but its architectural characteristics are not those of a *motilla*, nor those of a *morra*. Further investigations allow to affirm that it was a funerary place endowed with a highly symbolic, monumental and ritual significance and in use for almost a millennium, at least between 2465 and 1565 cal BC. The rituals practised at the site began in the Chalcolithic and were prolonged and multiplied during the Early and Middle Bronze Age. The documented architectural spaces do not show evidence of habitation, but the usual characteristics of prehistoric burial mounds. It presents a marker of the sunrise in the winter solstice, very striking and precise on the most conspicuous topographic feature of the whole horizon that surrounds the site: the Peña del Cambrón. Several corridors of the monument seem to present orientations with possible astronomical and/or topographic significance. It is especially significant that corridors B and 1 (as well as the cave galleries that extend below these corridors) are oriented towards the sunrise and sunset, respectively, at the winter solstice, the same time of the year when the sunrise over El Cambrón occurs. Other corridors also seem to present orientations with respect to the cardinal axes. The large building called 'Enclosure 4', probably destined for community prayers, is oriented to the solar ortho of the summer solstice. Often the winter solstice has an enormous symbolic significance, since it marks the moment of the year when the day begins to lengthen with respect to the night, a specific moment of the solar cycle identified as the victory of the sun over the darkness of winter and the rebirth of nature.

In short, the research we have developed allows us to affirm that the solstices, ancestor worship, the afterlife and the death-resurrection cycle were arguments on which the religion of the Motilla culture, which was previously completely unknown, was established (Benítez de Lugo Enrich and Esteban 2018; Esteban and Benítez de Lugo Enrich 2016).

It was not only solstitial events that drew the attention of the Motilla culture. Bocapucheros is a tumular monument with obvious orientations to the constellation of the Southern Cross, which at this time is not seen from the Northern Hemisphere but at that time was seen as one of the brightest constellations in the firmament, constituting an obvious calendrical marker (Benítez de Lugo Enrich *et al.* 2022). Consequently, different regions of the Motilla culture used sacred places with different ritual traditions, which related the ancestors to different astronomical events (Fig. 8).

Archaeogenetics: processes of social change, mobility and assimilation at the end of the 3rd millennium cal BC in the south of the Meseta

In recent years, several investigations have revealed an invasion of steppe descendants from Eastern Europe, which replaced almost all peninsular males just over 4,000 years ago. After studying the genomes of 271 inhabitants of the Iberian Peninsula from different historical periods, the results revealed an unprecedented picture of the transformation of the population throughout different prehistoric stages (Olalde *et al.* 2019).

Coinciding with the canonical date of the beginning of the Bronze Age, around 2200 cal BC, a complete change of Y-chromosome lineages is observed, while a strong influx of people descended from Eastern European steppe pastoralists is also apparent. Between 4000 and 4500 years – possibly coincident with the onset of the climatic event 4.2ka cal BP – the replacement of about 40% of the local population and almost 100% of the males occurred. The genetic results are very clear in this regard. Progressively, during a stage that may have lasted about 400 years, the Y-chromosome lineages present until then in the Copper Age were almost entirely replaced by a Yamnaya-Samara lineage, R1b-M269, of steppe ancestry. It was clearly a dramatic process from a biological point of view, although genetic data alone cannot tell what drove it. There is no evidence of widespread violence in that period.

As a paradigmatic example of this replacement, which does not appear to have been violent, Tomb 4 at

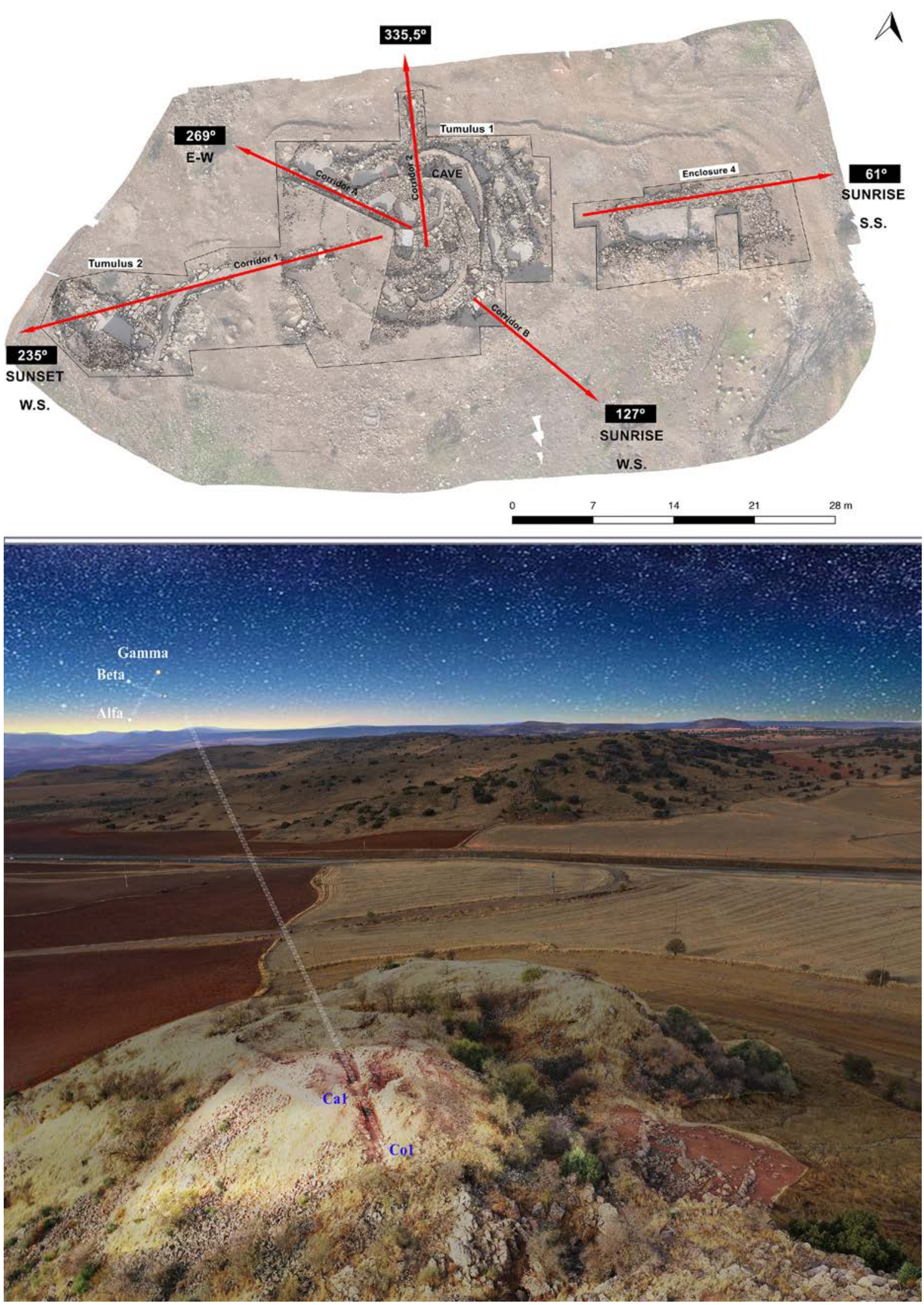

Fig. 8 – Castillejo del Bonete (top) and Bocapucheros (bottom) oriented to solar markers and the Southern Cross constellation, respectively. – (Drawing: José Luis Fuentes [Oppida]).

Castillejo del Bonete has been studied, an example of acculturation revealed by a couple who lived when the *motillas* were being built. This tomb is the only one at the site in which two individuals were buried, a male and a female; significantly, both have different genetic ancestries. The male presents steppe ancestry, while the female is genetically similar to pre-Copper Age Iberians. Both share a common burial ritual. The mode of burial of this man does not reveal significant cultural differences with those of other men buried in this monument. His grave goods are limited to his personal objects of daily use, as is frequent in the Bronze Age of La Mancha: a small carinated vessel, an archer's wristguard and a copper dagger; those of the woman, a globular pot, an awl, a very worn knife and two ivory buttons that buttoned some article of clothing on her chest. This tomb indicates that, although the Yamnaya-Samara genetic contributions began around 2400 cal BC in the north and centre of the Iberian Peninsula, they spread to the southern peninsula during the following 300–400 years. This pattern of peninsular male replacement is compatible with a founding effect of large peninsular male lineages, supported by the finding that males shared genetically more relatives than females. However, the genetic map model turns out to be more complex than that of two single sources of genetic contributions. It is likely that there were genetic contributions of Mediterranean provenance prior to the Bronze Age (Villalba-Mouco *et al.* 2021).

These population movements were both the cause and consequence of instability and social change at the end of the 3rd millennium BC, in direct relation to the phenomena described in the previous sections. These social and economic changes are especially visible in the south and east of the Iberian Peninsula, with phenomena such as the disappearance of the Chalcolithic culture of Los Millares or the origin of the cultures of El Argar and the Motillas, both related to a significant increase in population, the monumentalization of the territory, the spread of copper metallurgy and the clear use of symbolic resources. This period of changes is also characterized by the creation of new types of settlement. In short, archaeogenetic studies in recent years are providing information that was unsuspected until recently, which had not been detected through material culture, and which is fundamental and of great interest to understand the society of Later Prehistory in the south of the Iberian Peninsula.

Archaeogenetic studies have not been limited to the human species. Research on equids has allowed us to determine that all current domestic horses descend from ancestors that were domesticated in the steppes of the northern Caucasus. It has been found that between 2200 and 2000 cal BC a drastic change took place, whereby the genetic profile existing in the Pontic steppes began to spread beyond its region of origin, replacing in a few centuries all wild horse populations from the Atlantic to Mongolia. This new type of horse from the steppes of the northern Caucasus had a more docile behaviour and a more robust constitution in the vertebral skeleton. These characteristics were the trigger for the successful selection of these animals, at a time when travel with horses began to become widespread in Eurasia. This new type of horse coincided with the appearance of light chariots and the spread of Indo-Iranian languages. In contrast, it seems that the migration of Indo-European populations from the steppe zone to the heart of Europe towards the west during the 3rd millennium cal BC did not have this new type of horse as a vector of its expansion (Librado *et al.* 2021).

A relevant issue on this subject is that the *motillas* must have been places of watering and breeding of livestock; mainly ovicaprids, but also horses (and pigs, in third place). The numerous remains of equids found in the *motilla* of El Azuer (Aranda *et al.* 2008: 256) or the bones of horses found in the *motilla* of El Acequión (Martín Morales and Benítez de Lugo Enrich 2023) bear witness to this. Some samples of the latter – extraordinarily abundant, many of them with cut and axe marks – were included in the aforementioned palaeogenomic studies, with the following result: they correspond to an extinct Iberian autochthonous lineage, whose genetic contribution to current domesticated horses has been very scarce (Fages *et al.* 2019).

Archaeology: new types of archaeological sites

In the study of the Bronze Age in La Mancha it is necessary to take into consideration that the *motillas* are not the only type of archaeological site of the period. Until now it was known that the *motillas* coexisted with fortified settlements in elevated settings (*morras* or *castellones*), such as La Encantada (Granátula de Calatrava, Ciudad Real) and with other settlements in low-lying settings, such as simple villages or farms.

From studies we have carried out we know that the Motilla culture organized the landscape, in addition, with fields of silo-shaped structures and sacred places endowed with a strong symbolic charge that had been used since Chalcolithic times. Therefore, the limit between the Copper and Bronze Ages was, in La Mancha, in a certain sense, a moment of cultural continuity, rather than a hiatus or rupture, although allochthonous contributions were added to the traditional autochthonous base, as we have shown in the preceding section.

The archaeological excavations at Castillejo del Bonete have uncovered a prehistoric tomb complex

Fig. 9 – La Villeta. – (Photo: Authors' photograph).

on the southern edge of the Meseta. So far, two burial mounds have been found at the site – the larger of the two located over a natural cave with rock art and constructions inside –, communication corridors between burial mounds – some of them more than 20 meters long –, flared corridors oriented to the winter solstice that serve as access to the main burial mound, and a wide range of archaeological materials. These include an abundant collection of metal objects (Montero Ruiz *et al*. 2014), ceramics (Fernández Martín *et al*. 2015), rock art with human remains at their base (Polo Martín *et al*. 2015) and ivory buttons Benítez de Lugo Enrich *et al*. 2015b), funerary stelae brought from distant places (Delvene *et al.* 2020), in addition to bone remains (human or animal) and numerous personal ornaments – a collection with dozens of variscite beads (Odriozola *et al.* 2016), plus other wooden or bone beads (Benítez de Lugo Enrich et al. 2020a). These objects were deposited in pits excavated in the burial mound that were later covered again; others were deposited next to the dead. Some of these people ate food high in marine protein (Salazar García *et al*. 2013). The Castillejo del Bonete cave is a microfaunal reserve of the first order at a European level (Domínguez García *et al.* 2019). With the available data it is possible to affirm that it was a burial place endowed with a high symbolic, monumental and ritual significance. Bocapucheros (Almagro, Ciudad Real), may be another monument of this kind, whose research is just now beginning (Benítez de Lugo *et al.* 2022).

On the other hand, La Villeta is a field of 30 silo-shaped structures located at the Ciudad Real airport (Benítez de Lugo Enrich *et al.* 2007). None of them have been found with food or grain inside (Fig. 9). Since Neolithic times, food-producing societies have preserved food in silos in different ways. One of these are negative structures excavated in the ground in the form of pits. However, the lack in many cases of finds of grains or food inside should caution us against a functional interpretation of them as food storage spaces; for this reason, we suggest more generalized terminology, such as 'pits' or 'silo-shaped structures' in those cases where food remains were not attested. In most cases the silo-shaped structures have been found uncovered and filled with sediment and materials used in daily life, deposited in these places with a purpose yet to be verified. Their interpretation as garbage dumps has some weaknesses, given that traditionally garbage

has been thrown into the streets, blocks or fields, as fertilizer, rather than buried in confined places that would previously have been used as silos. Sometimes they also acquired a second function as ritual places after being used to store food, as human remains and votive deposits were deposited inside them. There are few cases of findings of closed silo-shaped structures; those known have appeared empty, plastered with clay and closed with different types of covers: slabs sealed with mud, querns reused as lids, and small false-corbelled domes (Benítez de Lugo Enrich *et al.* 2012). The 'pit fields' are usually located in flat areas, although there are also some on hillsides. This type of installation developed especially during Later Prehistory. From the Iron Age onwards, elevated structures (which had already been tried and tested in earlier times) were preferred. Pit fields have been a solution used for millennia, including historical times.

During archaeological survey, which was partially applied to the construction site of the Ciudad Real airport, a series of soil marks compatible with prehistoric silo-shaped structures were detected during the initial phase of removal of the topsoil. These were detected at a level of -30cm, in two locations: La Villeta I and La Villeta II. In La Villeta I 19 silos were found and in La Villeta II 11. A distance of 1582m separates the two sites. No structures or archaeological material were found on the surface. Their dimensions ranged between 30 and 180cm in diameter and 14 to 113cm deep at the time of their discovery. None of the pits were found with their cover. After the stripping of the topsoil, the dark brown colour of the fill was clearly visible, which contrasted with the orange colour of the natural substratum, rich in limestone fragments and nodules. The field of silo-shaped structures detected in La Villeta can be culturally ascribed to the agrarian communities that inhabited the southern Meseta during the Early Bronze Age.

In short, the studies carried out in the last decades have allowed us to expand the catalogue of archaeological sites that shared a territory with the Bronze Age *motillas* of La Mancha.

Archaeometallurgy: first securely provenanced El Argar-type halberd in the Motilla culture

The halberd was a specialized prehistoric weapon that appears in different European regions such as Germany, northern Italy, Ireland and the southeast of the Iberian Peninsula. Specifically, halberds are one of the distinctive material objects of the El Argar culture. They are associated with a class of warriors often also armed with daggers. These weapons, occasionally accompanied by metal oraments, such as gold bracelets, became markers of political power in tombs of central European men at the beginning of the 2nd millennium BC. Some halberds are extra-long, which is why they have been called "Stabschwerter". They were probably more symbolic than functional (Brandherm, 2004). Sometimes, their decoration with wolf's teeth is chronologically diagnostic. An example of this type is the halberd from Valdepeñas (Ciudad Real-Spain), with an oblique hilt mark which clearly reveals the direction of the handle (Brandherm, 2003, 377, no. 1384).

In the *motilla* of El Retamar we have recovered the only halberd known to date from a *motilla*. It has not been documented as part of a funerary assemblage, so it is not possible to suggest its association with a warrior elite as in El Argar. While this piece has not been found deposited as part of the grave goods of any particular individual, it is possible that the halberd comes from a destroyed tomb, of which multiple examples exist in the *motilla* of El Azuer, where 40 individuals come from tombs removed or destroyed by construction activity within the *motilla*. The halberd of El Retamar must have been an object of special social value, and possibly come from the core area of the El Argar culture. Its meaning in the context of the *motilla* of El Retamar will only be fully understood with the continuation of archaeological excavations, but it seems clear that it must have had different connotations to those that this type of object had in El Argar (Benítez de Lugo Enrich *et al.* 2022a; 2023b).

The halberd from El Retamar is of a clear El Argar type, characterized by a blade with a central rib and a wide handle plate (Fig. 10). This type of metal blade is especially concentrated in the nuclear area of the El Argar culture, corresponding to the coastal and pre-coastal regions of Almería and Murcia. The study carried out on this halberd has determined, in addition to its typology, its composition – arsenical copper – and the probable origin of the metal from the mining district of Linares. The chronology of the context where the halberd was recorded is consistent with the most probable period of production and use of El Argar halberds, which would be at the time of maximum aridity of the 4.2ka cal BP climatic event, between 2000 and 1800 cal BC.

In short, archaeological excavations of recent years have begun to shed new light on the weapons of the Motilla culture. The absence of specialized weapons has been one of the main characteristics of the Motilla culture. In spite of the intense archaeological excavations carried out in the last decades in different *motillas* and settlements of La Mancha, the halberd of El Retamar is the first securely provenanced,

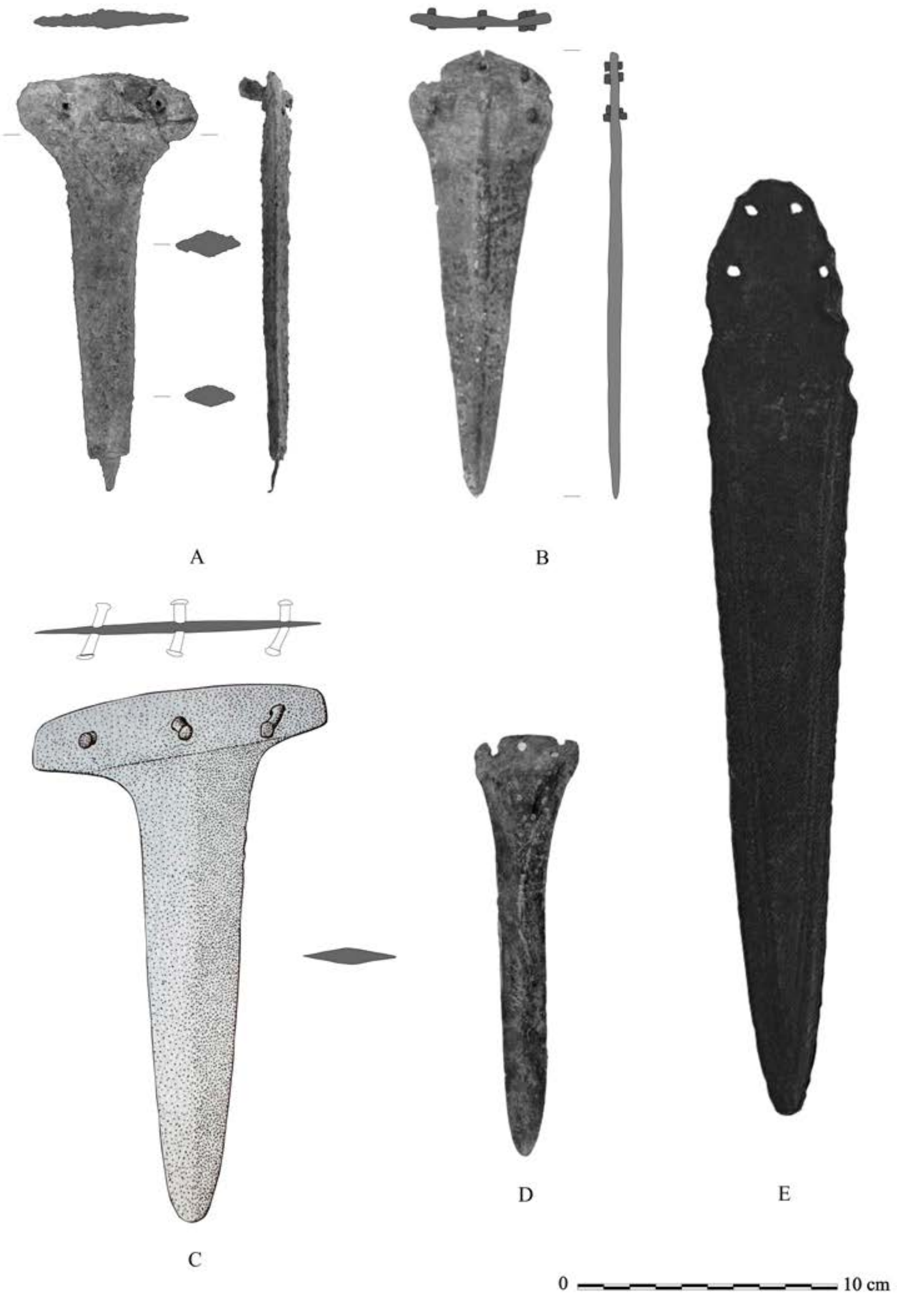

Fig. 10 – Halberds from La Mancha: El Retamar (A); Bocapucheros (B); near Ciudad Real (C); D: Villarejo-Peristeban (D); Valdepeñas (E). – (A: photo Gabriel Menchén. – B: after Blanco and Martínez 2022: fig. 8,2. – C: after Brandherm 2003: pl. 104,1426. – D: photo Museo de Cuenca. – E: after Benítez de Lugo Enrich et al. 2023b: fig. 4.34).

specialized weapon known from the Bronze Age of La Mancha.

Discussion and conclusions

During the early 21st century, we have seen advances and new efforts in the study of the Motilla culture, the cultural group of the Bronze Age in the Iberian Peninsula that inhabited La Mancha to the south and east of the Montes de Toledo. The discovery and study of new archaeological sites – such as La Villeta or Castillejo del Bonete – and the application of new scientific research methods – paleoecology, paleohydrogeology, archaeoastronomy, archaeogenetics, archaeometallurgy

– have made it possible to propose new models that broaden and improve traditional interpretations. In most cases, these are not mere conjectures or hypotheses pending verification. Nor are we dealing with a superficial use of archaeometric analysis, or the mere description of new archaeological sites. These new studies are verifying hypotheses and providing useful information that can explain the social dynamics of people who lived in the southern Meseta during the second half of the 3rd millennium cal BC and the first half of the 2nd millennium cal BC. The changes associated with the Motilla culture were much more complex than mere mechanisms of adaptation in the face of an environmental contingency; they are related to anomalous and exceptional climatic phenomena, but also to symbolic, social, political and economic aspects.

In 2010 the first inventory of *motillas* was published and began to explain their location and origin in relation to the 4.2ka cal BP climatic event, as opposed to other less solid explanations. In the last decade the traditional typology of sites for the Bronze Age of La Mancha has been expanded, incorporating new types of previously unknown sites; objects of a previously undetected class (weapons) have also been discovered in this territory. Likewise, we also know something about what we did not know before: the belief systems, including notions of the afterlife, of the people of the Motilla culture.

On the other hand, the definition of the *motillas* as 'fortified settlements on the plain' has been revised based on the facts described in the preceding pages. *Motillas* should not necessarily be considered settlements because people lived in them; people have also lived in places such as traditional hydraulic mills, and this does not mean that the mills are settlements. Two of the three best known *motillas*, El Acequión and El Retamar, lack Bronze Age towers. The tower of El Azuer may have another explanation different from the defensive one, as we have explained in this paper. The powerful perimeter constructions of the *motillas* could have functioned as dikes to protect the fresh water of the wells from the fluvial waters when the rivers ran again after the abrupt climatic event. The *motillas* were not built in the middle of a lagoon or riverbed as a defence system, but to seek water where the aquifer was accessible with prehistoric technology, at a time when surface water had disappeared. More than fortified settlements on the plain, the *motillas* are hydraulic infrastructures with large wells built by the first Europeans to exploit an aquifer on a regional scale.

A prehistoric village is mainly characterized by its huts. If the village is fortified, it has defensive elements that protect its dwellings and the main access to the village. In addition to towers, fortified gates are an essential element in fortified settlements. If the *motilla* is defined as a 'fortified settlement on a plain', as it has been interpreted in recent decades, the definition immediately leads to the idea of huts protected by walls with towers and gates fortified by towers and walls. There are Chalcolithic and Bronze Age settlements that follow this pattern and that are well known. But they are absolutely different from what we find in the *motillas*. Although there is evidence of some occupation in the interior of some *motillas*, no set of huts similar to a village has been described in the interior of any of them. From the fact that a family inhabits a *motilla*, it cannot be inferred that a *motilla* is a settlement. If one chooses to defend the idea that 'the settlement was outside the motilla', then what we have is an extra-mural settlement; we should not be talking about a 'fortified settlement'. The structures detected around the *motilla* of El Azuer are only mentioned in the last phase of the site, and before that, do they really constitute a settlement, or are they ancilliary constructions for the management and use of the *motilla* (storage facilities, ovens, some dwellings, etc.)? Moreover, size does matter: no settlement fits inside the *motilla* of El Azuer, nor inside the *motilla* of El Retamar. The surface area that the huts could occupy in El Azuer has not been reported. At El Retamar, the only known habitable space inside the *motilla* – Cut A, with a crescent-shaped floor plan – is located between the first and second 'wall' and measures only 31.1m^2 (Lenguazco 2008: 148; Benítez de Lugo Enrich *et al.* 2022). In a place of these dimensions, one or a few people could live, but not what we understand as a settlement. On the other hand, no *motilla* has been described with details of its gates or fortified access points. What has been found are 75 individuals buried around the well of the most studied *motilla*, that of El Azuer (Aranda *et al.* 2008: 253). Also, remains of four individuals have been found inside the *motilla* of El Retamar (Colmenarejo *et al.* 1987).

The use of the dead in Later Prehistory was a common occurrence to legitimize control of basic resources such as land or water. These data should not be overlooked. The *motillas* were certainly central places where people lived, but that does not necessarily mean that they were settlements. In a traditional mill there are warehouses, stables, ovens and places where people waited for their turn to mill. The people of the village went there and they were important places, central to the community, where people conversed and established relationships, but all this does not imply that they were villages. The *motillas* were hydraulic infrastructures in the Bronze Age of La Mancha that functioned as central places with villages and sites of different types around them, emerging as watering points in the middle of a dry and organized territory. Likewise, they were endowed with a strong symbolic charge, monumentalizing the landscape of the La Mancha plain during the Bronze Age, as great architectural landmarks in the plain. In short, we are witnessing a change and renewal of the traditional paradigm that explained the Motilla culture.

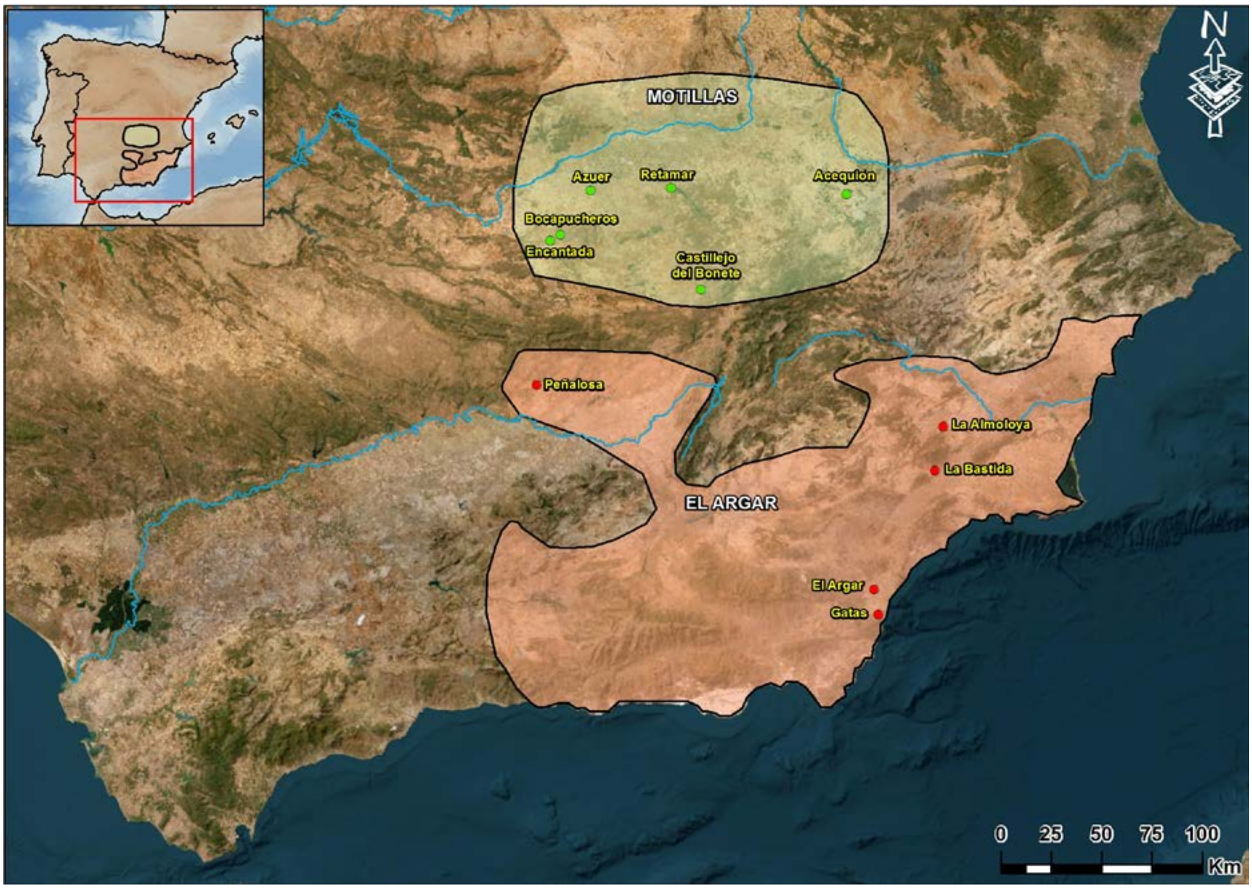

Fig. 11 – Respective distribution areas of the El Argar culture and the Motilla culture. – (Drawing: Jaime Moraleda).

The origin and *raison d'être* of the Motilla culture has been explained in a consistent and novel way, in relation to the most recent research from various scientific fields and in order to overcome the inconsistencies and gaps in its traditional interpretation. The end of the Chalcolithic did not bring to this territory a cultural collapse as in other regions, although it did mean an important change, by means of which a resilient autochthonous community incorporated foreign contributions to survive in a moment of climatic crisis. With diverse contributions and ingenious solutions, a new culture emerged in La Mancha, with new elements such as the *motillas*, but also anchored in ancestral traditions, such as the solstitial rites to the ancestors, practised in places like Castillejo del Bonete. This new culture of the Bronze Age of La Mancha presents clear differences with other contemporary ones like that of El Argar. It is not possible to confuse them or their respective territories. We have become used to being exposed to a map of the El Argar culture (cf. Lull *et al.* 2009: fig. 1) showing territorial boundaries with which we disagree (Fig. 11), as we have already indicated in a previous study (Benítez de Lugo Enrich 2020). The artificial language to which we referred on that occasion is born of an interpretation that conditions and subordinates what happens during the Bronze Age in the Meseta to the cultural developments of other nearby territories. That map that has already become a classic of El Argar studies, but the arm it 'throws' towards the territory in which the Bronze Age of La Mancha develops is denying this territory a personality of its own, ignoring its idiosyncrasy. The appropriation for the El Argar culture of territory to the north of Sierra Morena derives from the discovery in the La Mancha area of typical El Argar material culture elements (the El Argar cup found at La Encantada, for example), as if no other exogenous products were arriving to the area.

Another matter, quite different from the political domain, are the exchange networks on an interregional scale, through which objects circulated that could have been of prestige at a given time, and that the elites claimed for themselves in view of the growing social hierarchization: amber, variscite beads, ivory buttons, halberds or El Argar cups. We hope not to see in the future an updated map of the El Argar culture that extends another territorial language to Argamasilla de Alba, where the halberd of the *motilla* of El Retamar has been found.

In La Mancha, although there are silver deposits, silver ornaments are very scarce; at the moment,

for example, there are no known female burials of diademed women such as in tomb 38 of La Almoloya (Pliego, Murcia) (Lull *et al.* 2021), nor tombs of men with daggers or halberds. Although burials in La Mancha are not completely egalitarian, they are far from showing a highly stratified society. Most of the metal tools are polyfunctional; there is no weaponry and there is only one known case of a weapon: the El Argar-type halberd recovered in the *motilla* of El Retamar. Although there are visible differences between the cultures of El Argar and of the Motillas, their relationships and connections are evident.

Now that we have made advances in the explanation of the origin of the Motilla culture and in several of its aspects, we will need to turn to explaining the joint collapse of the cultures of El Argar and of the *motillas*.

Acknowledgments

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Water supply strategies in the Celtiberian Iron Age: the water strategies in the Baeturia Celtica

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From the 3rd century BC, the Subatlantic period was characterized by a significant improvement in climatic conditions. Rising temperatures and increased rainfall define this period, which contrasts with the 5th and 4th centuries BC, a period of greater aridity and thermal amplitude. Between the 5th and 3rd centuries BC, the settlement record in the southwest of the Iberian Peninsula shows a singular dynamic: the 'disappearance' of the Tartessian civilization and the emergence of a new form of settlement displaying evident links with the north of the Iberian Peninsula. This change in settlement models has been explained in social, economic and even linguistic terms, without paying attention to essential conditions for settlement, especially water supply. We present a comparative analysis of water supply strategies of the Early and Late Iron Age and pose the question as to how issues of water supply were successfully resolved by the newly arrived 'Celtic' populations.

Keywords: Baeturia, Tartessian culture, Celtici, agricultural use, drought

À partir du IIIe siècle avant J.-C, le Subatlantique se caractérise par une amélioration significative des conditions climatiques. L'augmentation des températures et l'augmentation des précipitations définissent cette période qui contraste avec les Ve et IVe siècles avant J.-C, période de plus grande aridité et amplitude thermique. Entre le Ve et le IIIe siècle avant J.-C. les traces de peuplement dans le sud-ouest de la péninsule Ibérique montrent une dynamique singulière : la « disparition » de la civilisation tartessienne et l'émergence d'une nouvelle forme de peuplement présentant des liens évidents avec le nord de la péninsule Ibérique. Ce changement des modèles d'habitat a été expliqué en termes sociaux, économiques et même linguistiques, sans prêter attention aux conditions essentielles à l'habitat, notamment l'approvisionnement en eau. Nous présentons une analyse comparative des stratégies d'approvisionnement en eau du premier et du second âge du Fer et nous posons la question de savoir comment les problèmes d'approvisionnement en eau ont été résolus avec succès par les populations « celtiques » récemment arrivées.

Mots-clés : Baeturia, culture tartessienne, Celtici, usage agricole, sécheresse

MÖ 3. yüzyıldan itibaren Subatlantik dönem, iklim koşullarında önemli bir iyileşme ile karakterize edilmiştir. Yükselen sıcaklıklar ve artan yağışlar, daha fazla kuraklığın ve termal genliğin olduğu, MÖ 5. ve 4. yüzyıllarla tezat oluşturan bu dönemi tanımlamaktadır. MÖ 5. ve 3. yüzyıllar arasında, İber Yarımadası'nın güneybatısındaki yerleşim kayıtları benzersiz bir dinamik göstermektedir: Tartessian uygarlığının 'ortadan kalkması' ve İber Yarımadası'nın kuzeyiyle belirgin bağlantılar sergileyen yeni bir yerleşim biçiminin ortaya çıkması. Yerleşim modellerindeki bu değişim, başta su temini olmak üzere yerleşimin temel koşulları dikkate alınmadan sosyal, ekonomik ve hatta dilsel açıdan anlatılmıştır. Erken ve Geç Demir Çağı'nın su tedarik stratejilerinin karşılaştırmalı bir analizini sunuyor ve su tedariki sorunlarının yeni gelen 'Kelt' halkları tarafından nasıl başarıyla çözüldüğü sorusunu ortaya atıyoruz.

Anahtar Kelimeler: Baeturia, Tartessian kültürü, Celtici, tarımsal kullanım, kuraklık

Introduction

Since 2017, a team from the CSIC, under the direction of Sebastián Celestino and Esther Rodríguez, undertook the archaeological excavation of a spectacular Tartessian building, Casas del Turuñuelo (Guareña, Badajoz), whose exceptional state of preservation is providing surprising data on the protohistory of the Iberian Peninsula (Rodríguez *et al.* 2021).

In 2018, a paved courtyard was identified, in which more than fifty horses had been sacrificed, along with other quadrupeds, in a ritual hitherto unknown in Peninsular archaeology (Celestino and Rodríguez 2019). This mass sacrifice was clearly related to the intentional burning and amortization of the building, which had been buried and abandoned by its inhabitants *c.* 400 BC (Celestino and Rodríguez 2019: 344). The discovery matched what was known from other contemporary Tartessian buildings, such as Cancho Roano and La Mata de Campanario: the intentional destruction and abandonment of large architectural complexes, apparently isolated in agricultural landscapes, at the end of the 5th century BC (Rodríguez Díaz 2003; Celestino 2022). This disruption of the habitat was also seen in open settlements, such as Palomar de Mérida, and in enclosed *oppida*, such as Medellín, to the extent that the disappearance of a people and a culture, the Tartessians, who had been dominant in the Early Iron Age of the SW Iberian Peninsula, can be attested (Berrocal-Rangel 1992; Paniego 2021: 29).

A few decades later, at the beginning of the 4th century BC, the SW was occupied by a new settlement system focused on hillforts, and a new archaeological culture that showed little or no relationship with its Tartessian predecessor. The bearers of that culture were identified as *Celtici*, or *Keltikoi*, because this is how they were called by Greco-Roman writers.

What put an end to the Tartessian culture and what was the reason for the possible arrival of these foreign populations has been one of the unknowns that archaeological research has sought to answer since their identification at the end of the 20th century.

At first, the end of the Tartessian culture was attributed to the 'arrival' of the Celts from the north', comparable to the arrival of the Germanic tribes who wiped out the Romans of the West. This was the traditional hypothesis, until it was revealed at Cancho Roano that this monumental building had been buried in rock-rose and heather wood, to be set on fire. There was nothing to indicate that this was the result of a violent act, but rather the result of a ritual of amortization. The repetition of such patterns at other contemporary sites, such as El Turuñuelo, has rekindled the question, leading to the acceptance that what has been documented is a surprising, large-scale and voluntary disappearance of an entire people: the Tartessians (Celestino and Rodríguez 2019: 344).

In the 1990s, this explanation was based on mere conjecture and linked to potential triggers such as a social uprising, a pandemic, or a large-scale migration, but with the latest findings the most convincing explanation – although not yet studied in detail – is based on evidence for climate change, with decades of drought making impossible the Tartessian way of life, which was closely linked to the agricultural use of the countryside.

Research

The end of the Suboreal period, between *c.* 1200 and 800 BC, contextualizes a Late Bronze Age with a general drop in temperatures and a rise in humidity, which meant a gradual increase in forest cover (Lamb 1977; Bouzek 1982; Bintliff 1982; Magny 1982: 36–37; Torres 2011: 32–33). This has been proven by pollen records from sites in the Southwest of the Iberian Peninsula (e.g., Trastejón de Zufre or Ratinhos). In these environments, the Atlantic dominance was evident with the proliferation of oak, birch, and chestnut forests (Pulido *et al.* 2007: 44; Hernández Carretero 2010: 359). These conditions undoubtedly led to an increase in available surface water, especially from snow-melt, and this has been proven in the Northeast of the Iberian Peninsula and in the North of the Spanish Plateau (Burillo *et al.* 1986; Gutiérrez Elorza and Peña Monné 1998).

In the following centuries, during the beginning of the Subatlantic phase, conditions slowly improved, despite being known as the Iron Age Cold Epoch (900–300 BC: Gribbin and Lamb 1978; Panizza 1985), favouring an increase in productive land and agricultural surpluses, which led to the strengthening of social relations and, especially, trade. The first centuries of the Early Iron Age coincide with the development of the Tartessian civilization (Celestino 2014). All this has led researchers to suggest that the populations of the Early Iron Age developed strategies of adaptation to the environment based on agriculture, and this seems to be demonstrated in the material culture and in the settlement system itself: cereal and legume deposits are common, together with agricultural implements, such as hand mills and, especially, an agricultural environment apparently favoured by the proximity to water sources.

However, by the end of 6th century BC, climatic conditions worsened again for human habitation, at least for two centuries, prior to the beginning of the so-called 'Roman Climate Optimum' (Gribbin and Lamb 1978; Hughes and Diaz 1994). What is of interest to our research is that this momentary worsening of climatic conditions (5th–4th centuries BC) coincides with the disappearance of the Tartessian civilization, and with a change in settlement strategies, in which agriculture would be replaced by extensive livestock farming and hunting, judging by the material remains found in the settlements of the Late Iron Age.

The study of water use strategies is one of the valid paths to confirming and understanding these massive changes. The worsening of climatic conditions at this time is a relatively accepted fact, but its consequences on settlement strategies and on the availability of water resources may have been greater than climatic fluctuations seem to indicate (Pulido *et al.* 2007: 45).

In this regard, some decades ago, Martín Almagro Gorbea (1996: 65–76) understood the development of the Tartessian civilization as a complex process of agricultural colonization, which would become palpable along the main rivers and the most travelled routes. Following this hypothesis, the large, isolated buildings of the Cancho Roano type began to be interpreted as evidence of an appropriation of the countryside, predecessors of the medieval *chateaux du champ* in France and Scotland, or the large Andalusian farmhouses (*cortijos*) of present-day Spain.

Boundary markers in the form of stone cairns or palisades would have accompanied this type of land use, indicated by pollen studies where, once again, the *dehesa* (or agroforest) has been identified as the dominant form of landscape, strongly anthropic and open, consisting of pastures, crops, and sclerophyllous

forests of quercine trees (Grau *et al.* 2004: 32–35, 70–72). They would feed the main sites, mainly in the form of cattle in Cancho Roano and La Mata (Castaño Ugarte 2004: 459, 467; Pérez Jordá 2004: 417). However, the material evidence found in these late Tartessian buildings is also overwhelming, confirming the existence of intensive leguminous and extensive cereal farming, in a society where private or family ownership is attested, as well as the availability of superior iron and steel technology (Celestino 2014: 131–146).

In this context, it would be logical to assume a close relationship between the settlements and water resources which, despite their abundance, would condition their location. From 400 BC onwards, the new settlements were different from the previous ones, as was their material culture, where the remains of livestock and hunting were predominant. Bovids and suids continued to be the dominant species, and such importance transcended mere economic interests (Berrocal-Rangel *et al.* 2018: 348), so much that this vocation and dedication to livestock has become a sign of regional identity up to the present day.

Methodology

To assess these proposals concerning the management of water resources, we have carried out spatial approximations of the relationships between six characteristic settlements of each period and their hydrographic landscapes (Fig. 1.1), considering the proximity to water sources, as well as the relationship of the hydrographic network with the agro-livestock environments and the prevailing communication system. Therefore, we proposed three main pillars. Regarding the hydrographic environment, we have calculated the shortest distances in a straight line to the nearest water sources: to the main rivers (basically the Guadiana River), to important tributaries, with a length greater than 100km, and to smaller watercourses whose perennial nature is attested for the period studied. Also, the distances to sources or springs, as recorded in the current cartography, have been captured, although this parameter has not been compared with the previous ones.

Secondly, we consider the network of roads and their intersections with rivers at fords. For our purposes, we have only considered historical roads, i.e., droveways, Roman roads, traditional roads and even roads prior to *c.* 1950 (Fig. 1.2).

Thirdly, the agricultural and/or livestock-rearing suitability of the immediately accessible land – calculated at a 2.5km radius – based on previous studies. This is based on current land-use mapping and, in this respect, two remarks are in order: Vineyards have been included among the agricultural lands, as this crop requires well irrigated and good quality land, so it can be assumed that, although in the SW Iron Age wine cultivation was selective and relatively scarce, these lands would have been used for agriculture (Celestino 2009: 116–120; Guerra 2009: 22). In contrast, land currently dedicated to growing olives has been counted as suitable for livestock rearing and forestry, given that the olive tree is adapted to much poorer subsoils and less demanding of water.

The sites from each phase under study are largely coeval (Fig. 1.1). Among the Tartessian sites, five of the best known in this area of the SW have been chosen: Cancho Roano, La Mata, Casas del Turuñuelo, Medellín (Almagro Gorbea 2008) and El Palomar (Jiménez Ávila 2005). They are of different types: the first three are large monumental buildings, Medellín is one of the largest *oppida* known in the SW, and El Palomar is an important village on the plain. All of them have provided copious agricultural remains: tools, querns, and agricultural produce, such as cereal grain deposits. Furthermore, they were occupied between the 6th and 5th centuries BC and abandoned, often suddenly, around 400 BC.

Likewise, among the Celtic hillforts, four walled sites from the *Baeturia Celtica* have been chosen: Castrejón de Capote (Berrocal-Rangel 2007), El Cantamento de la Pepina, El Cerro de las Monjas, Balcón de Pilatos, La Mesilla de Alange and Hornachuelos (Paniego 2021: 68, 102, 183; Rodríguez and Enríquez 2000: 277–278, 305–309). Although we know less about them than about the previous sites, there is no lack of agricultural tools, nor remains of agricultural produce, but the quantity of both categories of evidence is clearly less than that documented at the Tartessian sites. All of these sites were occupied between the 4th and 1st centuries BC.

Discussion

From our analysis of the available evidence, a number of insights can be gained. First, the distance to watercourses is broadly similar in both cases: An average of 10.1km for the settlements of the Early Iron Age compared to 6.8km for those of the Late Iron Age, but only considering watercourses with a continuous flow throughout the year. It is interesting to note that the settlements of the Early Iron Age are close to the main course of the Guadiana, while those of the Late Iron Age are close to its tributaries (Fig. 1.2). If we just look at the distance to the nearest watercourse, regardless if perennial or seasonal, then the similarity is even more pronounced: 307m versus 277m. According to these data, the proximity to water resources does not indicate differences in strategies between chronological phases (Fig. 2.1).

The relationship with fords does not show any differences between the settlements from the two

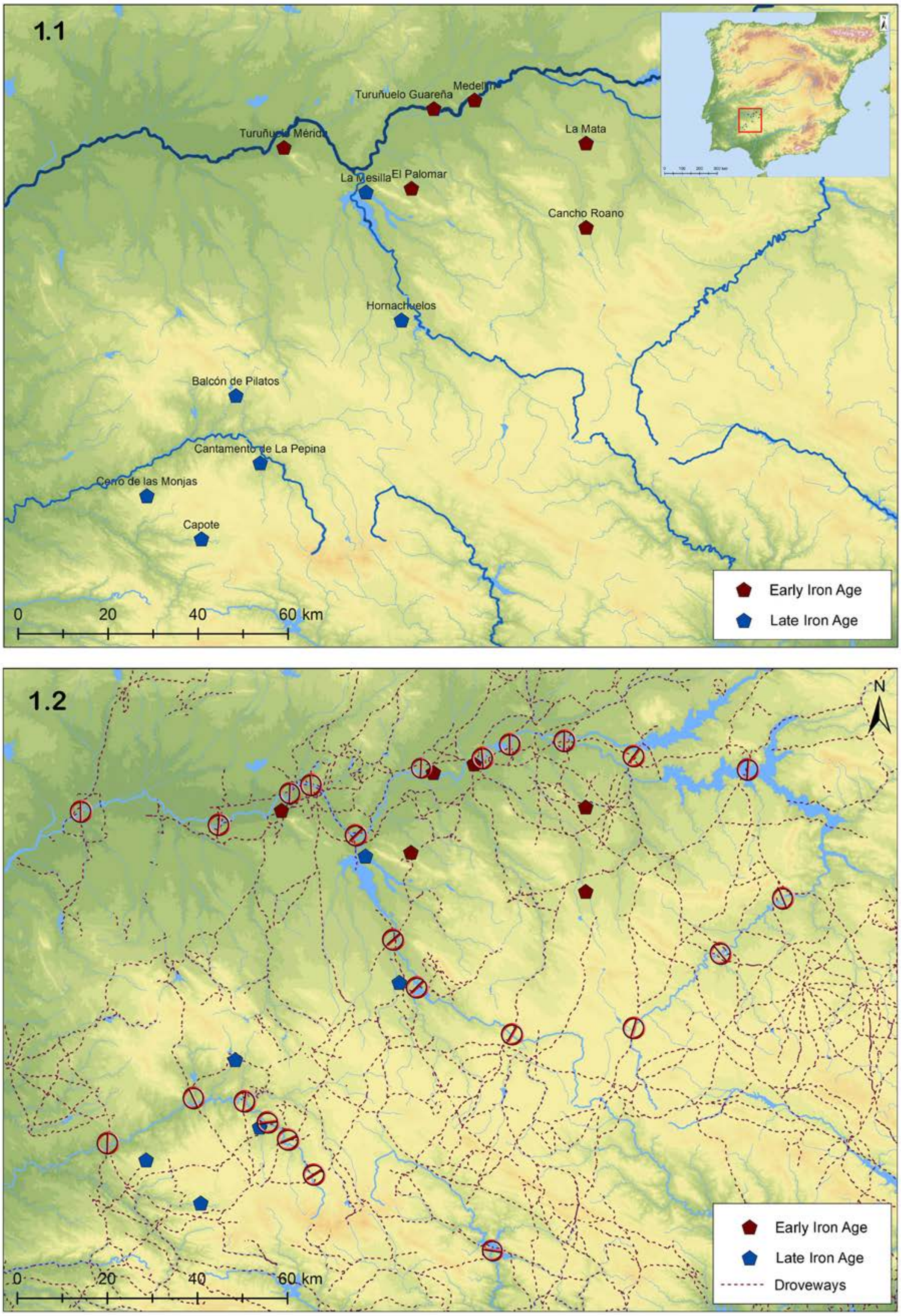

Fig. 1 – Location of the studied sites, in the Southwest of the Iberian Peninsula (1). – Spatial relationship between archaeological sites, traditional roads and natural fords (2). – (Maps: Authors' design).

2.1					Agricultural / Livestock / Improductive territories	Hectares under isochronous 30'
Cancho Roano	33200	-	35	0	22.25 / 77.75	2004
La Mata	15378	-	229	-	66.10 / 27.97	1590
Turuñuelo Gu	793	-	162	-	92.72 / 0	2010
Medellín	180	-	-	0	81.52 / 9.05	1844
Turuñuelo Mé	1277	25	644	-	90.79 / 0.56	1980
El Palomar	10271	10580	572	314	87.63 / 5.59	1611
Capote	66271	15827	-	0	5.79 / 61.45	1397
Cantamento	75407	1607	137	-	4.31 / 65.64	1270
Cerro Monjas	50891	5645	240	-	0 / 74.72	1015
Balcón Pilatos	64108	8611	606	40	13.86 / 66.06	1320
La Mesilla	4886	752	491	269	38.82 / 18.26	1394
Hornachuelos	34382	3533	319	-	56.96 / 33.16	1352

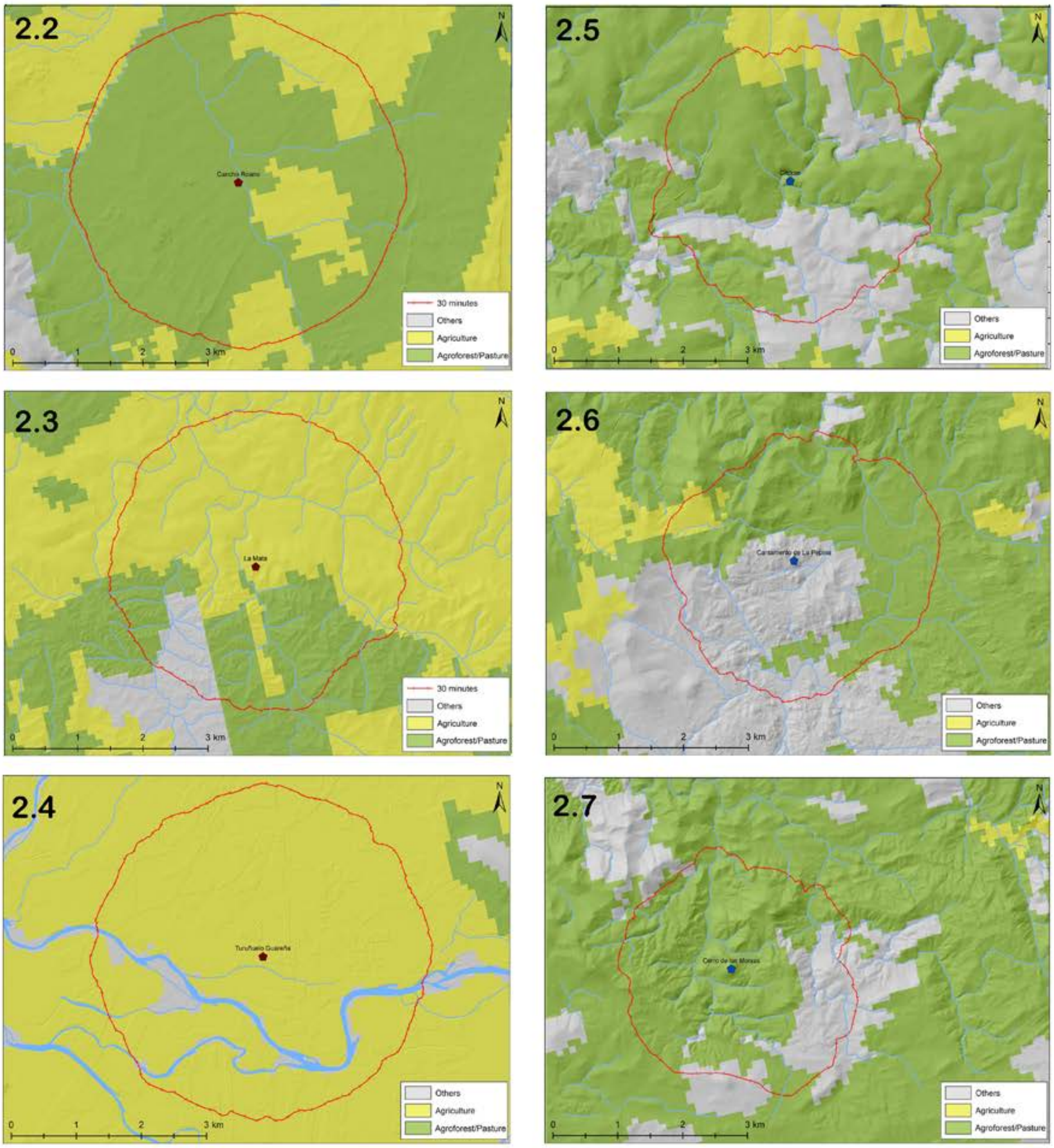

Fig. 2 – Table with the relationships of proximity to water and the percentage of land dedicated to agriculture/ livestock around the studied sites, with a radius of 2.5km, defined by the 30' isochrone (1). – Map of archaeological sites under study and coeval land use; EIA sites: Cancho Roano (2); La Mata (4); Turuñuelo Guareña (6); LIA sites: Capote (3); Cantamento (5); Las Monjas (7). – (Table and maps: Authors' design).

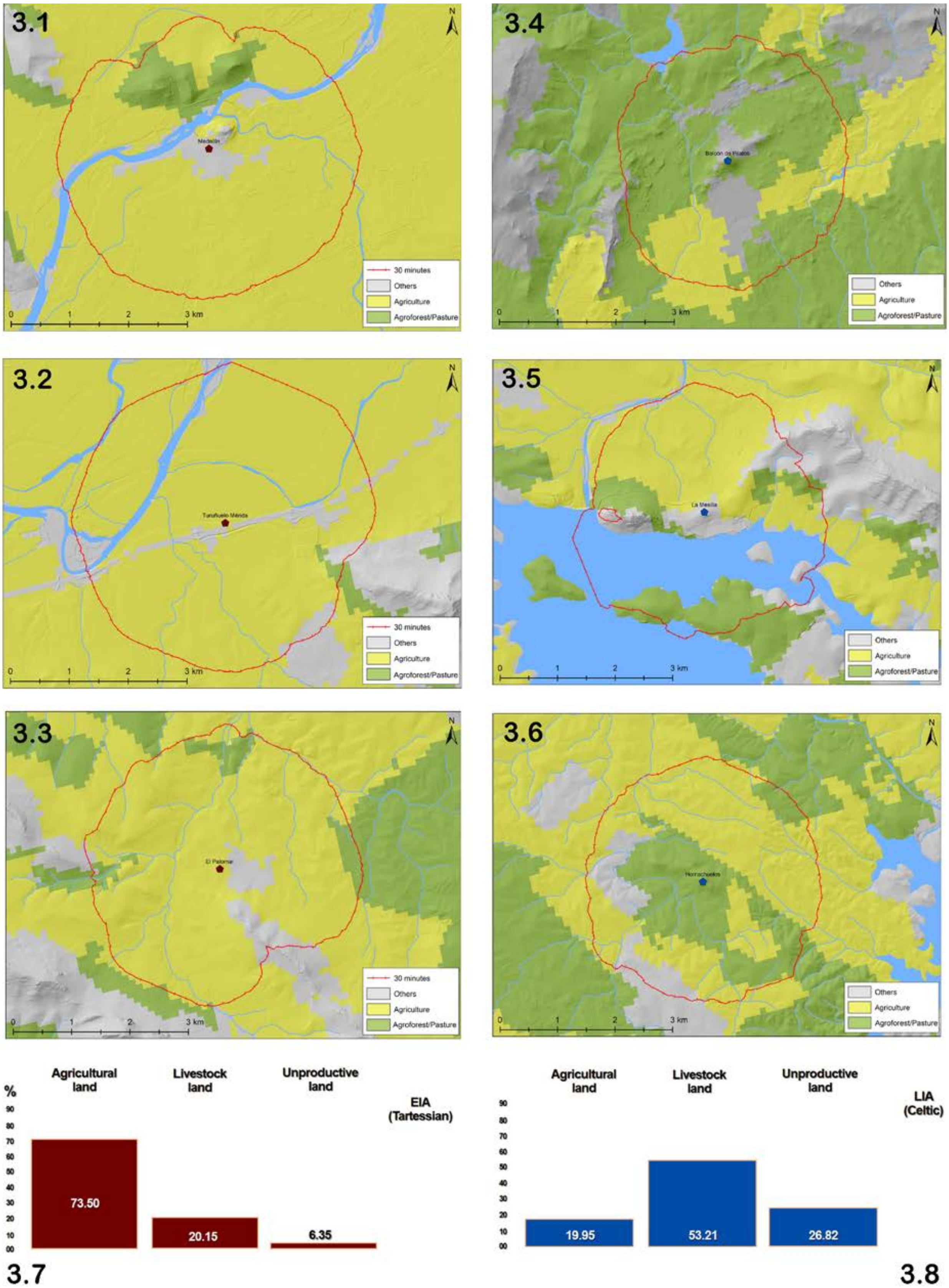

Fig. 3 – Map of archaeological sites and coeval land use; EIA sites: Medellín (1); Tutuñuelo de Mérida (3); El Palomar (5); LIA sites: Balcón de Pilatos (2); La Mesita de Alange (4); Hornachuelos (6). – Average percentages of EIA (7) and LIA (8) land use. – (Maps and graph: Authors' design).

different periods: three Early Iron Age sites are located near important fords of the Guadiana River (Medellín, Turuñuelo de Guareña and Turuñuelo de Mérida) and three Late Iron Age sites near fords of its tributaries (La Pepina, Hornachuelos and Las Mesillas). Once again, the only difference lies in the use of the banks of the Guadiana by the Tartessians.

However, when it comes to the use of agricultural land., differences are evident. In Figures 2.2–7 and 3.1–6 it is easy to see that the agriculturally productive lands, in yellow, dominate the immediate environs of the Tartessian settlements (in the left column), the immediate environs of the Celtic settlements are dominated by land best suited for livestock-rearing and forestry, shown in green and grey (in the right column).

These differences are best visualized in a simple bar chart (Fig. 3.7–8). The Tartessian settlements are surrounded by 73.50% of land suitable for agriculture, with livestock and forestry land only complementary (20.15%), and a very limited percentage of unproductive land (6.35%). It is, therefore, a rich agricultural ecosystem that requires a constant and significant supply of water from major rivers such as the Guadiana. The settlements of the Late Iron Age, on the other hand, are located on mainly livestock and forestry land (53.21%), with a significant percentage of unproductive land (26.82%) and a smaller amount of agricultural land (19.95%). This distribution is undoubtedly due to the higher elevations at which these settlements are located, but also to the distance from the main watercourses and the preference for smaller rivers, which may fall dry during summer.

Conclusions

The study of the water ecosystems of a dozen Iron Age settlements in the southwest of the Iberian Peninsula confirms differences in subsistence strategies between the settlements of the Early Iron Age, associated with the Tartessian culture, and those of the Late Iron Age, identified with the Celtiberian populations of *Baeturia*.

The spatial analysis of these twelve settlements confirms that the Tartessian settlements are close to the main river of the region, the Guadiana, and, in any case, to the lower courses of its main tributaries. On the other hand, Late Iron Age hillforts are located near these secondary rivers and other minor streams, some of which are intermittend. The analysis of the distance between settlements and river fords confirms this relationship but highlights a similar behaviour in both groups of settlements analysed.

The study of the agricultural surroundings of the settlements does reveal a clear difference between the Tartessian settlements, located in agricultural lands close to livestock and forestry lands, and the Celtic settlements, located in areas dedicated to livestock-rearing and forestry, with limited land suited for agricultural purposes.

These differences confirm the different water strategies adopted in this territory before and after the 5th century BC, strategies determined by its different ecosystems. Whether the cooling of the climate and a possible permanent drought was the reason for such a change of strategies or a consequence of different ethnic traditions needs to be confirmed by further research.

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General Session:
Current Research in the Metal Ages

Cathodoluminescence microscopy in cultural heritage: spatial characterization of pottery matrices over firing in earthen wares and stone wares

Mohammadamin Emami, Rémy Chapoulie and
Majid Montazer Zohouri

Cathodoluminescence microscopy has shed new insights into matrix evaluation of two different kind of pottery sherds via firing. Earthenware potteries from the prehistoric site of Haft-Tappeh (Elam Dynasty 1250 BC) and stoneware potteries (celadons) from Ardeshir-Khore (4th century AD, early Islamic Period) have been studied to characterize their fabrics and provenance by mineralogical phase decomposition. Both classes of pottery were first studied via routinely microscopically analytical techniques (optical- and scanning electron microscopy), X-ray diffraction and thermal analysis in order to determine their chemical-mineralogical phase constituents and firing temperature. Cathodoluminescence microscopy is favoured for demonstrating crystalline phase decomposition through diverse firing regimes in both kinds of pottery, and characterizing specific neo-formed crystalline phases for interpreting aspects of their raw material and provenance. Typical cathodoluminescence emission colour character of the minerals provides considerable clues for discriminating heating interval within the matrix of the sherds.

Keywords: Cathodoluminescence, mineralogy, ancient pottery, earthenware, stoneware

La microscopie par cathodoluminescence a apporté de nouvelles connaissances sur la température de cuisson de deux types différents de tessons de poterie, par l'analyse de leur matrice. Les poteries en terre cuite du site préhistorique de Haft-Tappeh (Dynastie d'Elam 1250 av. J.-C.) et les poteries en grès (céladons) d'Ardeshir-Khore (4ème siècle après J.-C., début de la période islamique) ont été étudiées pour caractériser leur production et leur provenance par l'étude de la décomposition de phases minéralogiques. Les deux types de poteries ont d'abord été étudiées via des techniques d'analyse microscopique de routine (microscopie optique et électronique à balayage), et par diffraction des rayons X et analyse thermique, afin de déterminer les constituants des phases chimiques et minéralogiques, et leur température de cuisson. La microscopie par cathodoluminescence est privilégiée pour montrer la décomposition de diverses phases cristallines en fonction des régimes de cuisson utilisés pour les deux types de poterie. Elle peut aussi caractériser des phases cristallines néoformées spécifiques, ce qui permet de définir certains aspects de la matière première ainsi que de sa provenance. Le caractère particulier de la couleur d'émission de cathodoluminescence de certains minéraux fournit des indices uniques pour distinguer des intervalles de cuisson au sein de la matrice des tessons de céramique.

Mots-clés : Cathodoluminescence, minéralogie, poterie ancienne, terre cuite, grès

Katodolüminesans mikroskobu, iki farklı tür çanak çömlek parçasının fırınlama yoluyla matris değerlendirmesine yeni bir bakış açısı getirmiştir. Tarih öncesi Haft-Tappeh bölgesinden (Elam Hanedanlığı, MÖ 1250) pişmiş toprak çanak çömlekler ve Ardeshir-Khore'den (MS 4. yüzyıl, erken İslam Dönemi) taş çömlekler (seladonlar), mineralojik faz ayrışması yoluyla bunların yapılarını ve kökenlerini karakterize etmek için incelenmiştir. Her iki çanak çömlek sınıfı da kimyasal-mineralojik faz bileşenlerini ve fırınlama sıcaklığını belirlemek için öncelikle rutin mikroskobik analitik teknikler (optik ve taramalı elektron mikroskobu), X-ışını kırınımı ve termal analiz yoluyla incelenmiştir. Katodolüminesans mikroskobu, her iki çanak çömlek türünde farklı pişirme rejimleri yoluyla kristal faz ayrışmasını göstermek ve bunların hammaddelerinin ve kaynaklarının yönlerini yorumlamak için belirli yeni oluşmuş kristal fazları karakterize etmek için tercih edilmiştir. Minerallerin tipik katodolüminesans emisyon renk karakteri, parçaların matrisi içindeki ısıtma aralığını ayırt etmek için önemli ipuçları sağlar.

Anahtar Kelimeler: Katodolüminesans, mineraloji, antik çömlek, toprak, taş eşya

Introduction

Ancient and historic potteries are mostly high temperature inhomogeneous objects. Over the evaluation of human history, different kinds of traditional potteries are classified based on their manufacturing processes and raw materials. Both of these issues have affected potteries throughout their mineralogical phase decomposition from exposure to heat (Huster and Pierce 2020; Hein and Kilikoglou 2020; Gliozzo 2020a). Pottery in its diverse types and functionality as a container is used to hold, maintain, preserve and melt (mainly metals and glasses) which have regularly been adjusted by alchemists, metallurgists, glass makers and architects, during a very long period of human history. Potteries were practically represented by the concept of the *chaîne opératoire* in terms of raw materials and manufacturing processes. They have been in use

from prehistory to describe traditions, cultures and ethnicities (Roux 2011; Teodorescu *et al.* 2021). Potteries were almost a context for transformation, fusion, even metamorphosis by exchanges and combinations. In archaeology and archaeological sciences, pottery and ceramic are metaphorically used to regard a society as becoming industrialized and communal, in regard to the diverse technological expertise combining to form a typical tradition and collective culture (Sedghi *et al.* 2022). The traditional pottery types are classified as earthenware and stoneware. However, developing of pottery manufacturing processes was dissimilar in the ancient world, and the flow of ceramic history clarifies the mainstreams of earthenware, to terracotta and stoneware (Carter and Grant Norton 2007).

In studying ancient potteries, some questions were always of interest, e.g., how was the pottery paste prepared and what was it made of? Which kind of additives were used? Under which temperature or firing condition (kiln atmosphere) have they been fired? All these aspects came to mind, since pottery consists of solid masses that were metamorphosed from clayey raw materials mixed with water and exposed to fire. Nevertheless, all types of pottery have preserved many aspects of their origin and resources after firing (Eramo 2020; Emami *et al.* 2021). Scientific strategies have delivered significant insights by means of routinely used laboratory methods, which have recently been complemented by high prestigious synchrotron facilities (Quartieri 2015; Tang *et al.* 2001; Gianoncelli *et al.* 2020). The characteristic mineralogical composition can be well studied by optical microscopy as well as diverse chemica and analytical methods such as petrography, thermal analysis and X-ray spectroscopic research (Teodorescu *et al.* 2022; Gliozzo 2020b; Emami and Emami 2020; Györkös *et al.* 2019; Noghani *et al.* 2018; Hein and Kilikoglou 2018).

Crystalline phase decomposition or reaction within the matrix of a pottery is a reflection of both crystallographic and chemical behaviour of a mineral in regard to its structural stability, which can be detected through heating, as well as specific trace element concentration which could be derived from the geological resources (Hayward, 1998). Replacement and spatial location of trace elements and structural imperfections within a crystal can define a characteristic crystal defect, or can be preserved in the form of an accumulation of impurities which have an affinity to be represented as a failure framework (Pagel *et al.* 2000; Artioli 2007; Hargittai, 2007). Failure frameworks will be observed in the form of luminescence colour, which is a fingerprint of a mineral established though both manufacturing temperature and geological genesis (Chapoulie *et al.* 2015).

Cathodoluminescence effect

Several materials, when irradiated by electrons of a few keV, produce a de-excitation phenomenon from the surface of a material. This phenomenon involves the emission of photons which release small quanta of energy in the range of a few eV, which can be converted into wavelengths, and can be seen in the visual light spectrum (Gillhaus *et al.* 2001; Marshall 1988). This is an optical and visible phenomenon which can be recorded with sensitive cameras. CL colour occurs in many materials, either natural or man-made. The physics of this phenomenon implies the electrons of the valence band of these materials when they are moved due to the primary electron beam interaction into the conduction band, and will recombine spontaneously with holes at either impurity sites (chemical defects) or defect centres like electron centres or hole centres (physical defects) (Cazenave *et al.* 2003; Chapoulie *et al.* 2005A; Remond *et al.* 1992). The energy difference is released as a photon at the wavelength of light from UV to near IR (Hayward 1998). Thus, the emitted energy (photon) is specific to the matter either of trace elements (e.g., chemical impurities) or lattice defects within the structure of the mineral, which can then be defined as a fingerprint. A combination of high resolution spatial cathodoluminescence spectroscopy in association with other methods is used to suggest a qualitative determination of the temperature interval in prehistoric potteries and to localize high temperature phases in celadon pottery types. This can occur by means of emitted CL emission bands of mineralogical constituents. CL microscopy needs an electron beam (cathode rays are accelerated by a few keV system) and a polarization microscope. Optical microscopy is currently used for imagery, when SEM can be used for determining the micro-fabrics and spectrometry (Chapoulie *et al.* 2016). CL microscopy allows the determination of spatial concentrations of specific crystalline phases which yield valuable information not easily seen by other methods.

Material and Methods

Samples

Two different types of pottery have been considered for this study. One set of pottery types is identified as five clay rich pottery sherds from Chogha Zanbil (2nd millennium BC) (Emami and Trettin, 2012). In addition, the second group consist of four celadon sherds from the historic city of Ardeshir Khwarah, Islamic Period (5th century AD) (Karimian and Montazer-Zohouri 2014). For the study, the sherds were prepared as thin and polish-sections. Two sets of samples were prepared; one set for petrographic research with 30 micrometers thickness and the

Sample	Dating	Functional Criteria
C.Z. 81-14-12	11th–12th century BC	Pots
C.Z. 80-16-17		
C.Z. 80-628-2	9th–10th century BC	Storage jars
C.Z. 80-16-8		
C.Z. 81-653-175	7th–8th century BC	
S:D_6-E_6-3	1st century to 10th–11th centuries AD	Pots
S:K_{13}-5		
S:M_8-19		
S:M_8-17		

Fig. 1 – Description and application of the objects concerning their archaeological context. – (Authors' design).

other set of samples with a thickness of more than 30 µm, which is much better for CL microscopy. Cross-sections of the potteries were dried for seven days at room temperature. The rest of the specimens were powdered in a tungsten carbide ball mill for thermal and XRD analysis. Tungsten carbide grinding media balls are the highest density media material for milling and crushing applications available as sintered rough balls. The tungsten balls have some advantages as semi-precision, high-precision balls. Tungsten carbide grinding balls provide excellent performance in wear-resistance and resistance to acid and alkali and avoid oxidation during friction of sensitive materials such as pottery. Due to the friction processes (since mostly pottery contains quartz particles in mm or µm size) and possible heat created, grinding time was set for three times each at 20 seconds (Fig. 1).

Experimental methods

Identification of crystalline phases within the body of pottery was carried out by X-ray diffraction (XRD) analysis (PANalytical X-ray Diffraction 1000G, Cukα, 40 kV, 40 mA, measuring time 1 sec per step) and was accomplished by using X'pert high score software and the quantitative study on phases content was performed by the Rietveld refining method. Scale factor, background, zero shift, peak profile and cell parameters were refined. Simultaneous Thermo Analysis (STA) was carried out on the prehistoric potteries with an instrument from Aeolos Netzsch, DSC 204F1 Phoenix (STA, 449C Jupiter with MS QMS 403C). The identification of minerals and characterization of textures was accomplished by the use of a Leica DM polarizing microscope and LAS V4.4 imaging software, based on optical and morphological properties of minerals. Each sample was studied using normal light as well as parallel and crossed Nicole. High-resolution ESEM observations were used with a Quanta FEG 250 FEI, fitted with an energy-dispersive X-ray spectrometer (Apollo XL30 EDX). CL imaging was performed with a Nuclide Luminoscope associated with a Leica MC125 optical microscope equipped with a CCD colour camera. CL images were collected with 10–12 kV accelerating voltage for the elctron beam, and 250–300 µA as current density. The impact angle of the electron beam was 30°, and the exposure time per capture was 45–72s.

Results and discussion

Crystalline phase composition and micro fabrics of the potteries

Both groups of studied materials have shown different mineralogical phase constituents from low temperature phases to high temperature phases (Figs 2 and 3). Bronze Age pottery sherds from Chogha Zanbil are characterized by their crystalline phases regarding their best preferred orientation which were developed from the aplastic additives within the matrix and decomposition products via firing. Indeed, the chemical-mineralogical reaction and decomposition have been overstated by several issues such as the grain size, composition of both the argillaceous host rock and the possible temper (chamotte or grog), the presence of aplastic inclusions and organic materials, the position of pot inside the kiln, and firing atmosphere (the redox conditions, soaking and cooling times) (Gliozzo 2020a; Maggetti *et al.* 2011). As a matter of fact, the matrix of ancient pottery can be divided into two clusters: carbonate rich (calcareous) or high carbonate rich (very calcareous) materials (Letsch and Noll 1983). The potteries from Chogha-Zanbil are characterized as carbonate rich materials (calcareous) and can be described by means of their phases (Fig. 2) (Emami and Trettin 2012).

Calcite also derived from raw materials as an additive. Carbonate reacts as a flux throughout the pottery production process, and therefore the firing temperature of high calcareous pottery is lower than calcareous potteries (Tite and Maniatis 1975). Calcite is the first mineral kept in attention as a thermo-barometer. Many parameters have been influential in calcite decomposition to calcium oxide, e.g., grain size,

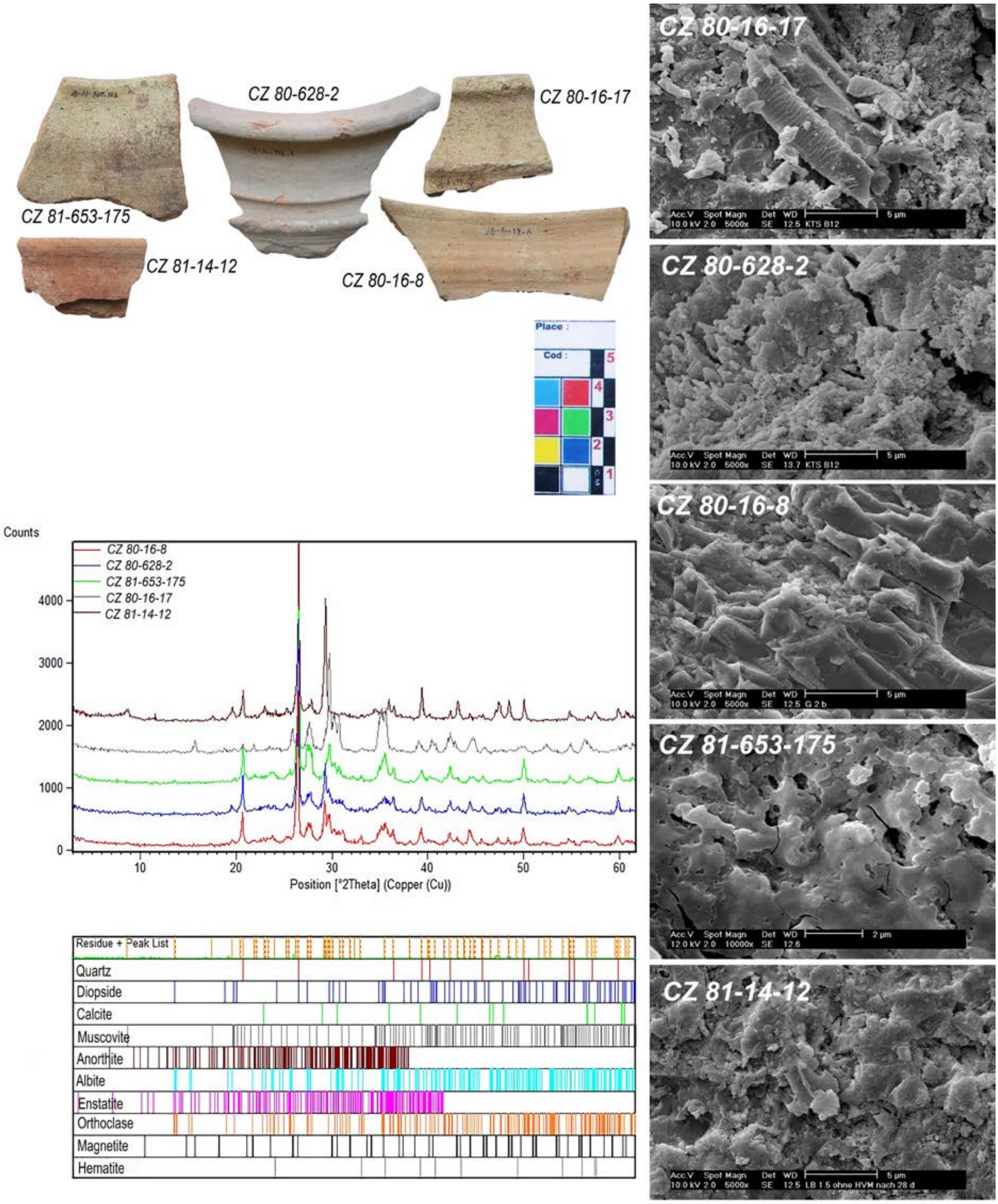

Fig. 2 – Investigated Bronze Age potteries from Chogha-Zanbil including their qualitatively phase determination and SEM picture of their texture. – (Authors' design).

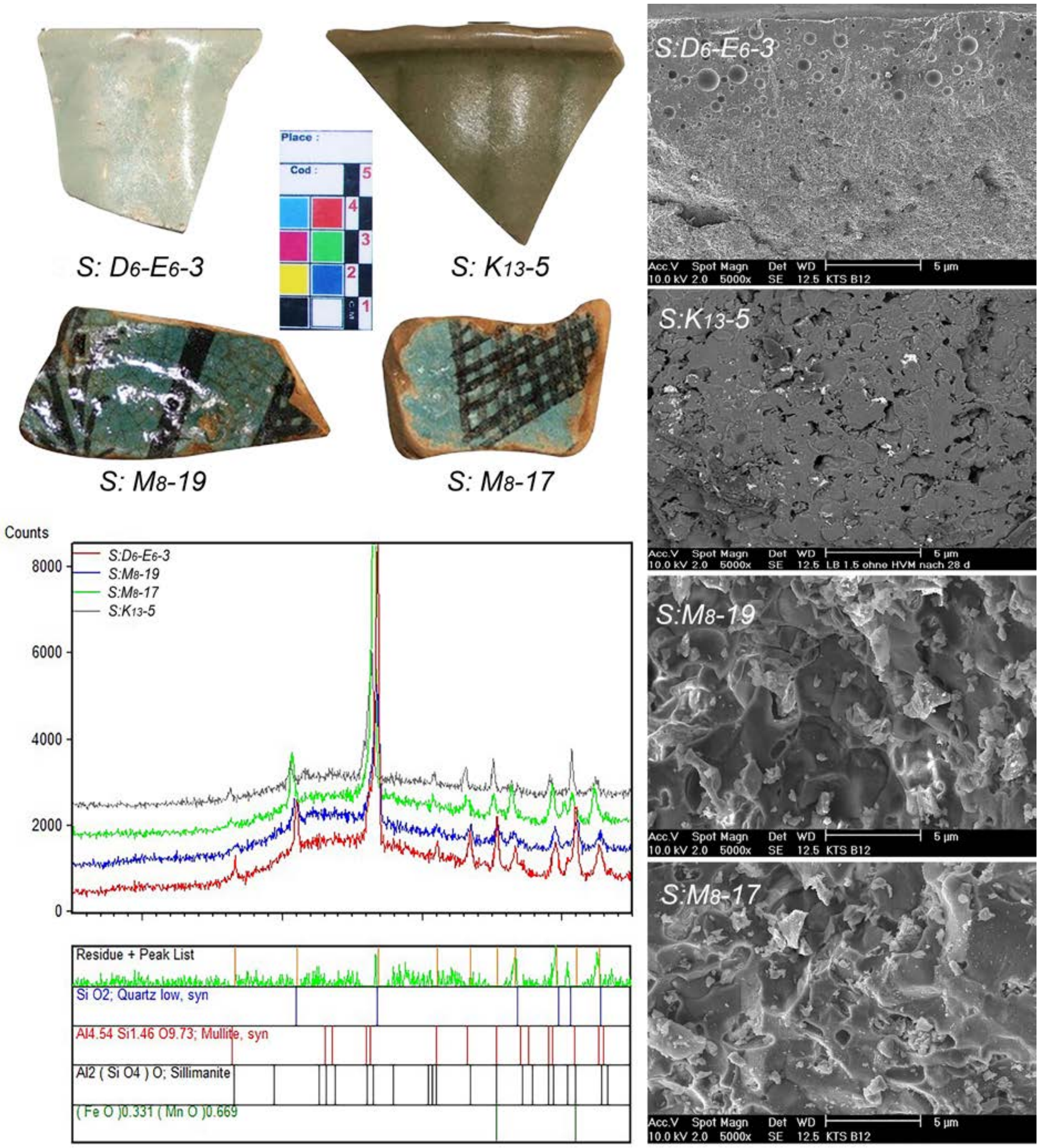

Fig. 3 – Investigated celadons from Ardeshir-Khore (4th century AC, early Islamic Period), including their qualitatively phase determination and SEM picture of their texture. – (Authors' design).

redox condition and soaking time. It occurred around 650–780°C and it was observed in the diffraction pattern ~ 2Θ=29°–30°. Few sharp peaks in a wide FWHM (full wide half maximum of a peak) such as diffractograms of CZ 80-16-8 in Figure 2, support the peak overlapping over the decomposition temperature of calcite.

Quartz is one of the mostly common constituents phases enriched in the earth's crust, and it can be found in every soil for pottering. Thermal stability of this mineral allows that it is always detectable within the matrix of a pottery. On the other hand, due to the reversible transformation via cooling and soaking time, cracks can occur and develop around the crystals (Fig. 2, CZ 80-628-2 and CZ 80-16-8). Quartz particles are mostly detectable in 2Θ=21° and 26°. Due to its sufficient reaction resistance, it always demonstrates sharp peaks depending on its grain size and shape (Emami *et al.* 2008).

Plagioclases and alkali-feldspars primarily originated from the host stones, crushed and processed as additives; however, anorthite can also be formed by the reaction between muscovite and calcite under an oxidation atmosphere and T > 850°C (Rathossi and Pontikes 2010a).

Hematite occurred due to the oxidation atmosphere during firing. Magnetite certainly results after the Fe2+ release from illite in the breakdown of raw clay, and remains over oxidation of hematite (T > 800°C). Both minerals in this case came from oxidation processes in the kiln. Best preferred orientations of hematite and magnetite appear at 2Θ=33° and 2Θ=35°.

Diopside is an end-member of clinopyroxene that can be synthesized by a reaction between illite and calcite, at ~ 950°C–1100°C (Riccardi *et al.* 1999). CaO released from the breaking of calcite which was supposed to migrate over wider fields of temperature and cause the formation of high temperature Ca-rich phases such as anorthite and pyroxene at a temperature around 950°C (Riccardi *et al.* 1999). Pyroxene appears at ~ 2Θ=33–35°.

According to mineralogical data and STA results, the Bronze Age potteries were fired under high temperature around 950°C, and all reactions within the matrix have to be completely verified. The fabrics of the potteries are in a good vitrification stage, due to the glassy structure of the micro texture which is shown by the presence of bubbles as a sign of high temperature reaction (Fig. 2, CZ 80-653-175), and the matrix which shows high carbonatic filament texture (Fig. 2, CZ 80-16-8, CZ 81-14-12).

Consequently, the same condition can mostly be seen within the crystalline phase constituents of the celadon samples. As a matter of fact, the main phase within the structure is involved from the quartz peak, followed by different and all high-temperature phases, e.g., sillimanite, mullite and iron-manganese oxides. Except for Fe-Mn oxides, all other phases are typical minerals, which were demonstrated in Iranian celadon from Kish Island and China (Tite and Wood 2005; Emami *et al.* 2019).

A high-temperature manufacturing process can be identified at the interface body-glaze by the presence of well-formed bubbles within the glaze (Fig. 3, S:D6-E6-3). The sinter structure of the body of celadon is shown by the viscose texture and glass filaments within the micro fabrics of the celadon (Fig. 3, S:K13-5, S:M8-19, S:M8-17). According to the diffraction patterns of crystalline phases, we can look at the firing conditions; from this point of view, the celadon samples were all similar. Diffraction patterns show a peak in the curve course between 2Θ=18°–30°, which indicates vitrification and glass formation.

The presence of mullite and sillimanite indicates a firing temperature up to 1050°C. The formation of mullite is derived from kaolinite clay (Martín-Márquez *et al.* 2010). Mullites are mostly characterized as needle-like structures which are not clearly visible under the optical microscope and have to be detected through SEM examination. Indeed, it is also difficult to arrive at a universal characterization of the manufacturing technology, since the structure of the kiln and the arrangement of potteries within the pit played significant roles in finishing the body of the potteries. Particularly, the manufacturing process and evolution of the glassy matrix were influenced by diverse raw materials in different steps (Khizanishvili and Mamaladze 1969). According to the results from simultaneous thermo-analysis (STA) we can suggest:

1. Illite clayey raw materials: produce spinel at ~ 800°C, followed by formation of mullite needles at ~ 1000°C.
2. Kaolinite clayey raw materials: with decomposition of kaolinite to metakalinite at ~500°C. Metakaoline is metastable and directly will decompose to spinel over forming of amorphous silica at ~800-950°C. The process will be completed at ~1050-1275°C by forming Al-Si spinel, mullite and cristobalite.

Cathodoluminescence microscopy and petrological properties

Cathodoluminescence microscopy is a method with a very wide range of applications in archaeological sciences, mainly for determining and localizing the chemical reactions within the pottery matrices as well

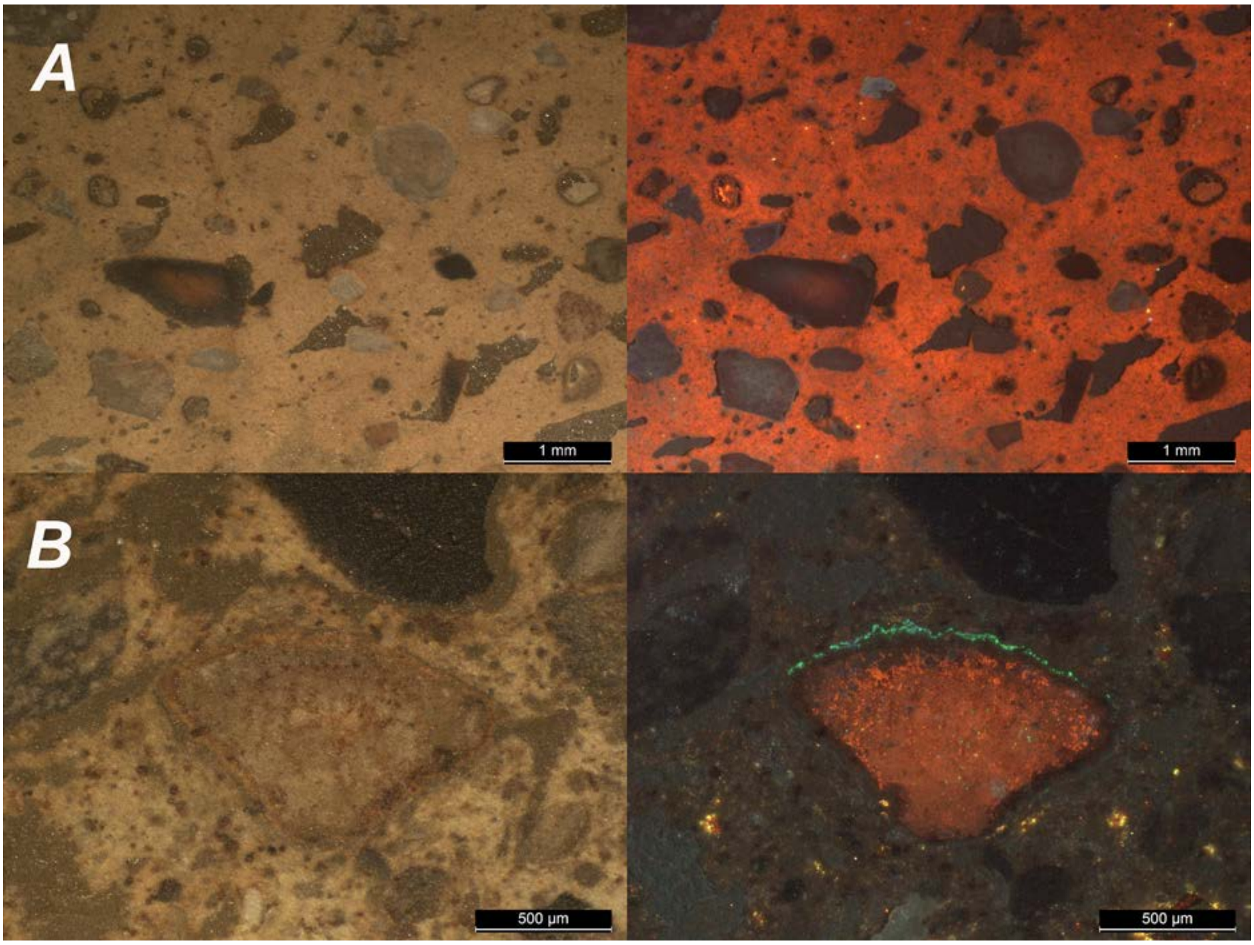

Fig. 4 – Observation of Bronze Age calcareous pottery, left with normal light and right with luminescence colour. A: The high orange CL colour appeared through Mn^{2+} activators in calcite. B: calcite with green luminescence activation through Sm^{2+}, Dy^{3+} and Tb^{3+} within the fluvial calcite. – (Authors' photograph).

as its provenance (Boggs *et al.* 2002). As a matter of fact, through pottery manufacturing processes the clayey matrix will be changed and recomposed to new high-temperature crystals, which may contain some residues from the original raw materials (Rathossi and Pontikes 2010a; Rathossi and Pontikes 2010b). Heat treatment has to be followed by heat transport of elements, and heat transport generates new crystalline phases by means of decomposition of previous phases. The reaction in many minerals is mostly obvious from the external aspect. By studying the textural composition of the potteries, the areas of reaction and the reaction products can be very useful for understanding the archaeomaterial characteristics (Maggetti *et al.* 2011; Lin *et al.* 2019; Maggetti, 1982). High-temperature earthenware potteries are the ones which have been mainly made from calcareous-rich or calcareous material. The calcareous matrix is very sensitive to the temperature interval, through which secondary as well as high-temperature new crystals will be created mostly above 800°C (Cultrone, *et al.* 2001). Cathodoluminescence may characterize the new crystals or reaction products based on their generated CL colour (Blanc, *et al.* 2020, Hunt, 2013, Weiss, *et al.* 2016). The CL colour of the matrix of such kinds of pottery is changed based on the firing temperature. Applications of CL imagery in sedimentary rocks and carbonates were mostly focused on their diagenetic condition. Despite the geological circumstances through sedimentation and production of carbonates, diagenetic reactions in carbonates can appear over firing of carbonate minerals by means of the zoning effect on the crystals. Typical CL emitting centres of carbonates would yield through Mn^{2+}, Fe and rear earth elements (REE). Among them Mn^{2+} is the most important luminescence activator in sedimentary carbonate (Richter *et al.* 2003). The two groups of studied potteries produced different effects of luminescence regarding their mineral constituents and matrix.

The Bronze Age potteries from the 2nd millennium BC showed a typical orange-yellow CL activation colour within the matrix of the potteries (Fig. 4a). The high intensity of colour is due to the existence of Mn^{2+} within the calcite structure and the alluvial sedimentation condition. Magnesia-calcite is a metastable form of calcite structure which occurred rather widely as

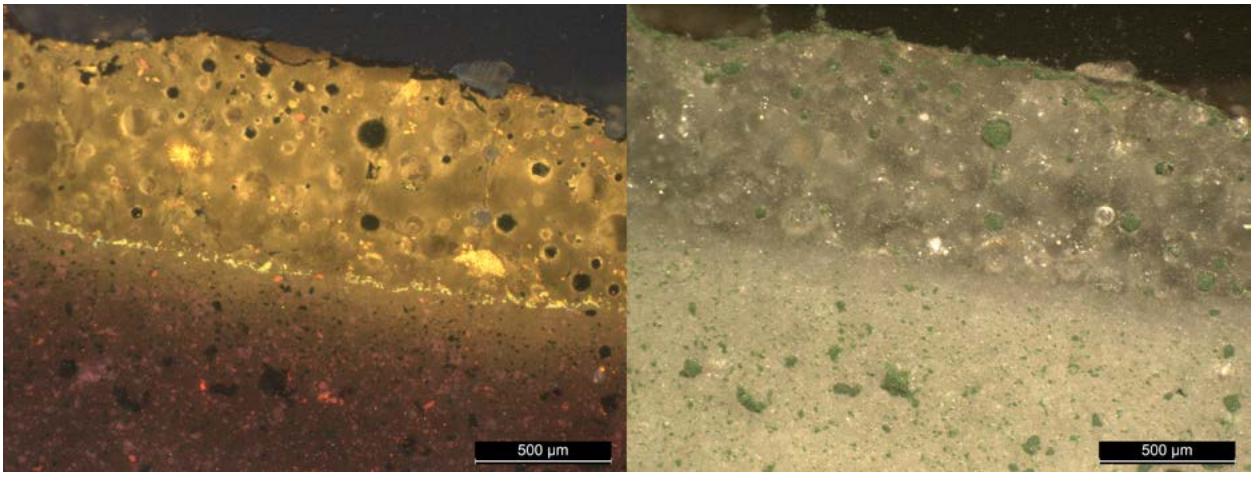

Fig. 5 – Celadon samples under CL microscope. Picture left, luminescence colour of the celadon and picture right, pottery under normal white light. – (Authors' photograph).

biogenic skeletal material and as cement in some modern marine sediments. The high intensity of the orange CL colour of fired pottery is related to the fluvial origin of the clayey residues. As a matter of fact, the area of the investigated potteries around Chogha-Zanbil in the southwest of Iran is classified as a great geosyncline in Eurasia (Emami and Trettin 2012). The green CL colour around the non-completely decomposed calcite has been observed by means of the high enrichments of Sm^{2+}, Dy^{3+} and Tb^{3+} as important REE activators within the calcite structure (Fig. 4b) (Machel 2000).

Celadons have different characteristics, based on their mineral constituents as well as their reaction through firing. Celadons mainly consist of quartz, and therefore they have been classified as stoneware potteries. The CL feature of celandons is directly dependent on the activation colour of quartz crystals within the matrix of the pottery. The CL colour of quartz is mostly complex, since the CL activation of quartz was influenced by its formation varieties, e.g., magmatic, sedimentary and metamorphic (Götze and Zimmerle 2000). The CL feature of quartz and quartz-bearing rocks leads to the characterization of three CL types of quartz: violet, brown, and non-luminescing quartz, whose existence represents rocks at distinct stages of formation temperature and thermal fluids (Zinkernagel 1978). Variances in the luminescence feature of quartz make it possible to distinguish between diagenetic and detritial quartz: violet luminescing quartz in igneous rocks, brown luminescing quartz in regional metamorphic rocks and non-luminescing or weak luminescing quartz formed in sediments (Zinkernagel 1978; Götze *et al*. 2001).

The celadons in this regard have been characterized by violet to bluish CL, which is probably due to quartz originating from an igneous reservoir (Fig. 5, left). The zoning effect of celadon was added by means of glazing the surface. The reddish dots within the matrix can be verified as calcite or dolomite. The zoning effect through CL of the glaze-body interface of celadons with bright yellow CL emissions was recorded in the interface area (Fig. 5). These interface layering formations throughout new crystals might have appeared when there was an amalgamation process between the siliceous matrix and the glaze. However, celadons displayed high orange-yellow CL emission at the interface, which would support the idea of a double-firing process, since few new crystals would be formed at the interface area. This hypothesis of double-firing has been described in previous work on Islamic ceramic (Chapoulie *et al.* 2005b).

Conclusions

In this study, the application of CL microscopy has proven to be a useful method in archaeometrical research. CL emission imagery gives essential information regarding the origin of additives and the manufacturing process (i.e., firing conditions). Synopsis through studying the technological know-how and provenance of clayey based materials is still a developing scientific approach. Based on the results, it is shown that earthenware potteries had local origins and were fired in different stages. In contrast, the firing process for creating stonewares did not remain constant; however, they were particularized by means of completed sintering.

Moreover, the CL emission characterizes the matrix of a pottery by defining the stages of firing: once for fired clay, or twice in celadon cases, firstly in consideration of the mineralogical constituents of the samples utilizing a single clay source, and secondly in samples in which more firing progress has been exercised. Furthermore, the origin of the additives can be classified through the CL emission colour of quartz

aggregates as well as calcite in calcareous potteries. Quartz aggregates in celadons are believed to have an igneous origin, while the Bronze Age potteries had proved sedimentary origins. In the future, analytical approaches will be carried out with CL microscopy, to know more about the *chaîne opératoire* of a group of potteries, even if the corpus is not similar enough in terms of their texture and fabrication.

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At the mercy of the waters of the Turkish Euphrates: Tilbes Höyük and its possible performance as a regional sanctuary of a goddess during the 2nd–3rd millennia BC in northern Mesopotamia

Jesús Gil Fuensanta and Alfredo Mederos Martín

In the second half of the 1990s, the archaeological site of Tilbes Höyük (Birecik, Urfa, southeastern Turkey) provided extensive deposits of all phases of the Early Bronze Age (EBA) I–IV. Throughout its excavation, between the years 1996–1999, the site provided remains of consecutive religious buildings from EBA I–III, interpreted as sanctuaries, on the same location at the site. In that sector of Tilbes Höyük, E4aE3E8, remains of burials and a persistent ritual were also found, as well as iconography and indications associated with fertility, dated to the same period, and later, until the Middle Bronze II. Based on these findings, we think that part of the function that this site had could be associated with the existence of some fertility cult, due to the existence of alleged sanctuaries throughout several centuries of existence, in addition to a settlement that survived the historical ups and downs of the period (3rd millennium and first half of the 2nd millennium BC) of the Early and Middle Bronze Age. Especially considering that in other phases of the same period, larger places, such as Surtepe, in the Birecik area were vacated.

Keywords: Northern Mesopotamia, southeastern Turkey, Early Bronze Age, Tilbes Höyük, shrines, burials, inter-site violence

Dans la seconde moitié des années 1990, le site archéologique de Tilbes Höyük (Birecik, Urfa, sud-est de la Turquie) a fourni d'importants gisements de toutes les phases de l'âge du Bronze ancien (BA) I à IV. Tout au long de ses fouilles, entre les années 1996 et 1999, le site a fourni des vestiges d'édifices religieux consécutifs de BA I à III, interprétés comme des sanctuaires, au même endroit du site. Dans ce secteur de Tilbes Höyük, E4aE3E8, des restes de sépultures et un rituel persistant ont également été trouvés, ainsi qu'une iconographie et des indications associées à la fertilité, datées de la même période, et plus tard, jusqu'au Bronze moyen II. Sur la base de ces découvertes, nous pensons qu'une partie de la fonction qu'avait ce site pourrait être associée à l'existence d'un certain culte de la fertilité, en raison de l'existence de prétendus sanctuaires tout au long de plusieurs siècles d'existence, en plus d'un site qui a survécu aux hauts et aux bas historiques de la période (IIIe millénaire et première moitié du IIe millénaire av. J.-C.) du Bronze ancien et moyen. D'autant plus qu'au cours d'autres phases de la même période, des localités plus grandes, comme Surtepe, dans la région de Birecik, ont été abandonnés.

Mots-clés : Nord de la Mésopotamie, sud-est de la Turquie, âge du Bronze ancien, Tilbes Höyük, sanctuaires, sépultures, violences entre sites

1990'ların ikinci yarısında, Tilbes Höyük (Birecik, Urfa, Güneydoğu Türkiye) arkeolojik alanı, Erken Tunç Çağı (EB) I–IV'ün tüm evrelerine ilişkin geniş kapsamlı birikimler sağlamıştır. 1996–1999 yılları arasında yapılan kazılar boyunca alanda aynı yerde İTÇ I–III dönemine ait, kutsal alan olarak yorumlanan ardışık dini yapıların kalıntıları bulunmuştur. Tilbes Höyük'ün E4aE3E8 bölgesindeki aynı döneme ve daha sonrasına, Orta Tunç II'ye kadar tarihlenen mezar kalıntıları ve kalıcı bir ritüelin yanı sıra doğurganlıkla ilgili ikonografi ve göstergeler de bulunmuştur. Bu bulgulara dayanarak, bu alanın sahip olduğu işlevin bir kısmının, tarihi günümüze kadar varlığını sürdüren bir yerleşimin yanı sıra, yüzyıllar boyunca var olduğu iddia edilen kutsal alanların varlığı nedeniyle bazı doğurganlık kültlerinin varlığıyla ilişkilendirilebileceğini düşünüyoruz. Erken ve Orta Tunç Çağı dönemlerinin (MÖ 3. binyıl ve 2. binyılın ilk yarısı) iniş ve çıkışları. Özellikle aynı dönemin diğer evrelerinde Birecik bölgesindeki Surtepe gibi daha büyük yerlerin boşaltıldığı dikkate alındığında.

Anahtar kelimeler: Kuzey Mezopotamya, Güneydoğu Türkiye, İlk Tunç Çağı, Tilbes Höyük, Türbeler, Mezarlar, Yerleşim yerleri arası şiddet

Introduction. The Early Bronze Age rising times of the Tilbes Höyük and neighbouring sites

The 3rd and 2nd millennia BC in northern Mesopotamia are linked to the spread of local Bronze Age cultures. The 3rd millennium roughly covers the Early Bronze Age (EBA), while much of the first half of the 2nd millennium BC includes the Middle Bronze Age period, phases I and II.

The 3rd millennium BC did not present much specificity in the archaeological stratigraphies north of Karkemish until the mid-1990s; especially the periods Early Bronze Age (EBA) I to EBA III. In the Karababa area (near Samsat), more than hundred kilometres upstream, we identify an archaeological sequence that served as a stand in the Turkish Euphrates area (Algaze *et al.* 1994) since the 1980s. Until the late 1990s, it was difficult to distinguish EBA I–IV levels, just by the compact ceramic

technology of the Middle Euphrates, but it is true that subtle changes in the techno-ceramic bulk as well as certain shapes that act as fossil directors, can serve as indicators for the division between the four main phases of the EB in the Middle and Upper Euphrates in accordance with the North Mesopotamian (Syro-Turkish Middle Euphrates) chronology (Deckers *et al.* 2015; Schwartz 2017) (Fig. 1).

In the 1990s projects focused on the late Early Bronze Age urbanization in the Turkish province of Urfa were carried out on the Turkish Euphrates and conducted

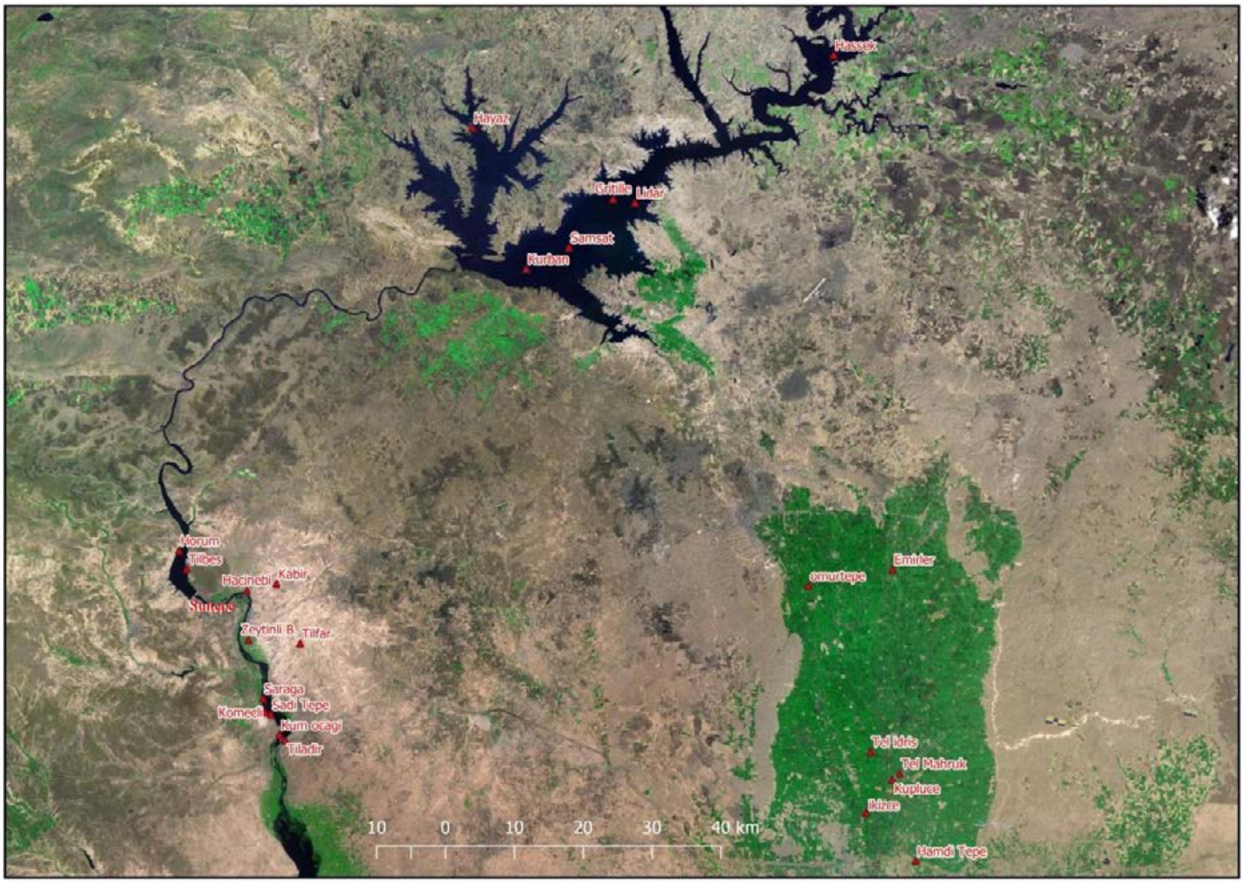


Fig. 1 – Harran plain and Tilbes Höyük in Syro-Turkish Middle Euphrates, northern Mesopotamia (a). – The Birecik dam after completion, year 2000 (b). – (a: after Can 2018: 115 fig. 8; b: photo courtesy of Nezih Başgelen).


a


b

Fig. 2 – Tilbes Höyük, view from the hills (a). – Tilbes Höyük under Dam waters, year 2000 (b). – (Photos: Tilbes Project/MAET).

by Patty Wattenmaker at Kazane Höyük (Wattenmaker 1997; Wattenmaker and Misir 1995) or Guillermo Algaze at Titriş Höyük (Matney and Algaze 1995). Archaeological excavations in Tilbes Höyük within the borders of Keskince (Tilmusa) Village, Birecik district and located on the east bank of the Euphrates River, were carried out in 1996–1999 within the framework of the Birecik dam rescue excavations. During the digs that lasted until the year 2000, architecture, grave remains and small finds belonging to all these Bronze Age periods were unearthed in this mound, which consists of a few phases; the site's ancient occupation finished during the late Medieval period. The excavations, conducted by J. Gil Fuensanta on the Tilbes mound and its vicinity, were part of a joint project with *Şanlıurfa* Museum (Turkey) and several universities, including Alicante (Spain), Prague/Pilsen (Czech Republic) and Widener (USA) (Gil Fuensanta *et al.* 1999; Gil Fuensanta 2007).

There is possible evidence that several of the sites north of the Birecik dam, and on the right bank of the Euphrates River at its source, suffered erosion in the late Early Bronze Age. Tilbes Höyük was just over 1.5ha when it began to be excavated, but in Late Antiquity the site was damaged by the Euphrates river, and much of the location was eroded and destroyed by the waters and periodic floods of the Euphrates. The geological data proved that the Tilbes Höyük, main conical mound, was half cut by the Euphrates sometime in Late Antiquity, perhaps at the end of the Roman period; consequently, the excavated areas close to the river bank must have been more centrally located at the time of its occupation, i.e., the EBA period (Fig. 2a–b).

The local meaning of Tilbes is the 'Last Hill'. It was a conical mound located near the Euphrates measuring over 22m in height above the river bank, and at the time of the archaeological excavation it measured 110m × 100m. The cultural deposit of Tilbes Höyük was revealed to be at least 14.5m deep. The slopes were like stepped terraces, and the western slope facing the Euphrates was steeper than the others. The Euphrates was flowing through a wide basin right below the mound; therefore, it can be suggested that this site was a thoroughfare for travellers. As a result of excavations, it has been revealed that the mound of Tilbes Höyük was occupied from the Chalcolithic, with a stratigraphy 1.5m deep, of Late Ubaid 4, and was covered by 2m-deep river silt. After a hiatus of occupation, the mound had been settled again from the EBA I until the Middle Bronze Age II. It was abandoned for a while after the Middle Bronze Age.

The continuity of the EBA sanctuary at Tilbes Höyük

Tilbes Höyük during the years 1998–99 yielded remains of a ritual Early Bronze Age III burnt building and other shrines dated to previous phases (EBA I and II). The earliest shrine, from the Early Bronze Age I, located in the original centre of the mound, was on a mudbrick platform and presented a possible access from the East, the sunrise. The building had stone walls and a clay horned altar during the Early Bronze Age I, 3025 (2900) 2875 BC. Another shrine above the same spot was also documented, worse preserved, during the Early Bronze Age II. This religious space suffered a fire at the end of the later shrine, dated to the Early Bronze Age III, 2675 (2550–2500) 2450 BC, and the building was better preserved. It has a narrow entrance from the West, the sunset, to a small room with a stone pavement that gives access to the main room. It is a mudbrick pillar, a rectangular hearth and two small clay-horned structures, one of them near the pillar. In the phase of the Early Bronze Age II, two stone cists with infant burials appear in the interior of the Tilbes Höyük sanctuary. But later on, the former shrine areas of Tilbes Höyük, although no longer built, in the Early Bronze Age IV mainly include newborns, between 7 and 9 months old, deposited in pits outside the building, perhaps linked to a cult of rebirth and fertility. Among the faunal remains, plenty of kid bones were recovered

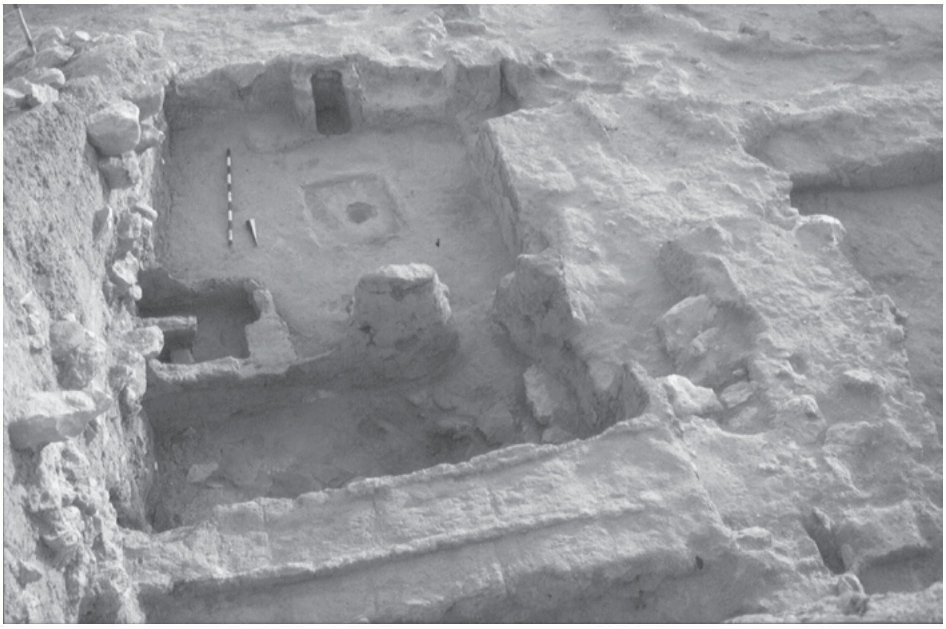


Fig. 3 – Early Bronze Age III Sanctuary, Tilbes Höyük, Square E4aE3E8, year 1998. – (Photo: Tilbes Project/ MAET).

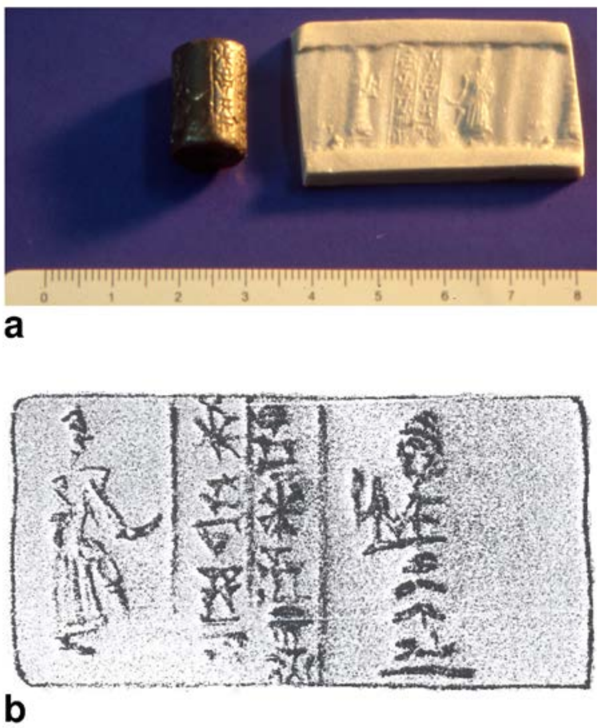


Fig. 4 – Middle Bronze Age I cylinder seal, Tilbes Höyük, A2–A6 area, surface. – (a: photo Tilbes Project/MAET; b: drawing by Funda Genç).

from EBA III/IV period (Gil Fuensanta *et al.* 2019: 56–61 fig. 4–9). Pottery, beads and bronze artefacts were found in the graves in the layers dating back to the EBA period. The presence of painted ware of Karababa (a tradition of the Upper Euphrates and Tigris region and rooted in Transcaucasia) was reported for the EBA III/IV levels. EBA III/IV levels also yielded goddess figurines in terracotta (Fig. 3).

These discoveries of the 3rd millennium do not appear to be restricted to a local phenomenon of the time in southeastern Turkey, but are present in other regions with a similar date. The best parallels are the Temple B of Arslantepe VIB, Early Bronze Age I, 3000–2800 BC, with two mudbrick pillars and a rectangular hearth, and the shrine of Level XIV of Beycesultan, west Anatolian Early Bronze Age II, 2500–2400 BC, with two other mudbrick pillars and a large structure of horns.

A cylinder seal was found outwith of any clear context. The original seal appears to be a product of a Babylonian-trained seal-cutter, working in his homeland, North Syria or southeast Anatolia, between the 19th and early 17th century BC. Sometime during the period of its use, the original inscription was removed and the seal received a new text, reinterpreting the divinities depicted as Nergal and his consort Mammitum (Charvàt and Gil Fuensanta 2001) (Fig. 4a–b).

The cylinder seal and impressions found in Tilbes Höyük reveal an affiliation to goddesses of fertility and waters, such as Mamittum or the same narrative of the anegraphic seal, which refers us to a procession that heads to a small building with astral symbols, typical of incarnations of goddesses with this affiliation and purpose. In a previous interpretation we thought that in its first conception it would be a seal belonging to an official or priest of the temple/sanctuary of Tilbes of a possible divinity linked to waters or fertility, ‘Adad abubi’, ‘Adad of the flood’, but we could not obtain more precise data at the time to confirm such a hypothesis.

According to what was excavated in Tilbes Höyük between 1996 and 1999, it is deduced that the place was an important location of exchange throughout the Middle Bronze Age (MBA) I, and that, together with the

Fig. 5 – Iron Age III clay figurine, Tilbes Höyük Square A2A6, year 1997. – (Photo: Tilbes Project/MAET).

concept of a local-regional sanctuary, this must have been the key to the persistence of its settlement, continued from the start of the LC5/EB1 transition to MBII.

The Tilbes mound provides abundant evidence on the use and deposition at the site of alleged terracotta figurines of goddesses, linked to fertility and waters during the MBA and Iron Age. They would be possible incarnations of the same goddess: Mamittum, Ishtar, Anahita, names given by the different peoples and cultures that predominated in the territory over time. You can even see subtle changes in details and characteristics of the representation of the goddess over the centuries, and from the archaeological point of view it is striking that many of these figurines have been found intact, with their complete extremities, as is not the case with other stone or terracotta figurines found in Surtepe (Fig. 5).

During the Late Iron Age, Roman and medieval periods the site also saw sporadic occupation. Tilbes Höyük stood at a strategic point where the Euphrates river flows out of the mountainous tracts of eastern Anatolia into the alluvial plains to the south, and the importance its position was enhanced by the existence of an important ford at this spot (Fig. 6a–b).

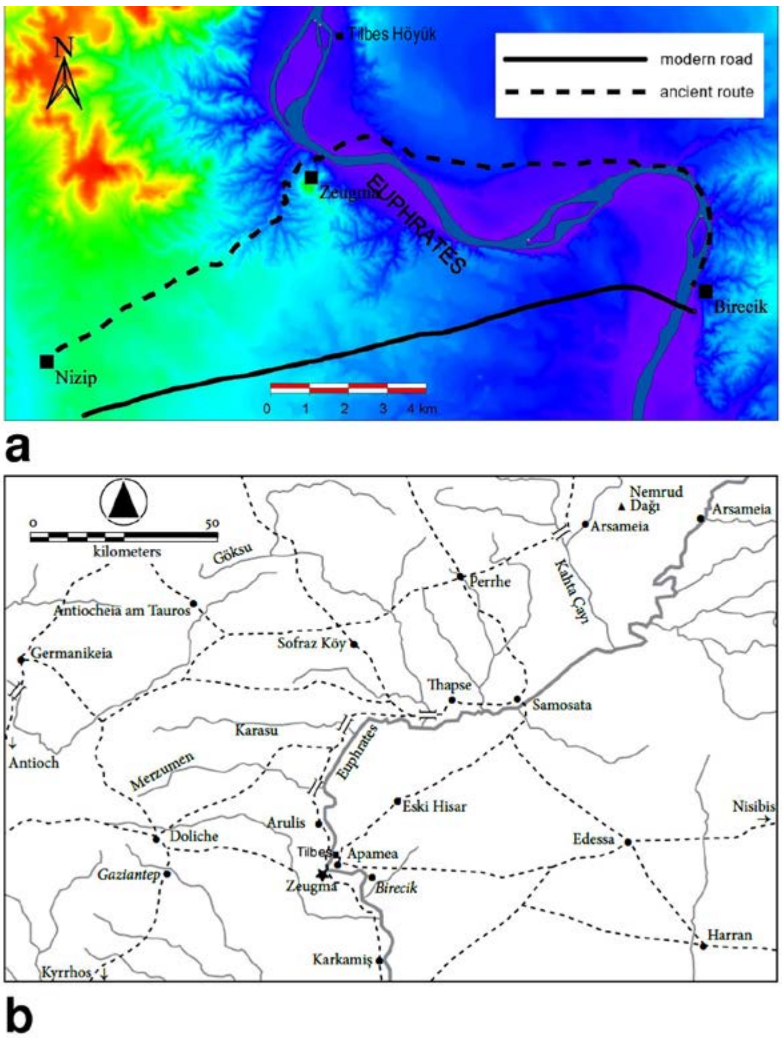


Fig. 6 – Ancient route to Roman Seleucia-Apamea/Zeugma in comparison to Tilbes Höyük (a). – Tilbes Höyük at the intersection of ancient Roman routes between the west and east of the Middle Euphrates (b). – (a: after Karaka 2008: fig. 5.14; b: Ailward 2013: fig. 2).

The ford made Tilbes Höyük a key site for monitoring and controlling traffic along the course of the river, especially regarding wholesale deliveries of bulk materials of which the southern civilizations demanded more and more. Ever since the beginning of the 3rd millennium BC, Tilbes Höyük is likely to have seen the passing through of continuous supplies of Anatolian metal, stone and wood to consumers both along the twin rivers of Mesopotamia and in and around the mountains and plains along the east coast of the Mediterranean. In the last century of the 3rd millennium BC, the generalized movement of mountain populations towards the south is well discernible archaeologically (Charvàt 2002 and pers. com.). At Tilbes Höyük, it could well account both for the presence of northern Mesopotamian and Anatolian elements of material culture and for the intensification of the local settlement, visible in the proliferation of habitation structures.

The discontinuity of Tilvez Höyük, Tilöbür and Surtepe

At the archaeological site of Tilvez, on the edge of the Turkish Euphrates (Birecik, Urfa), interesting artefacts and evidence were discovered within levels from the late Early Bronze Age. Tilvez Höyük, modern Eski Meteler, 4.2km south Tilbes Höyük, was occupied during the EBA I, EBA III and the Roman period, when it was part of Apamea, in the dipolis of Zeugma. It had an extensive occupation (up to 3ha) during EBA III, and in addition there abound the tombs of EBA III date in a depositional level after the abandonment of the buildings, as we found in another sector of the site. The EBA III remains there have evidence of having been submerged after the EBA IV period (Fig. 7a–b).

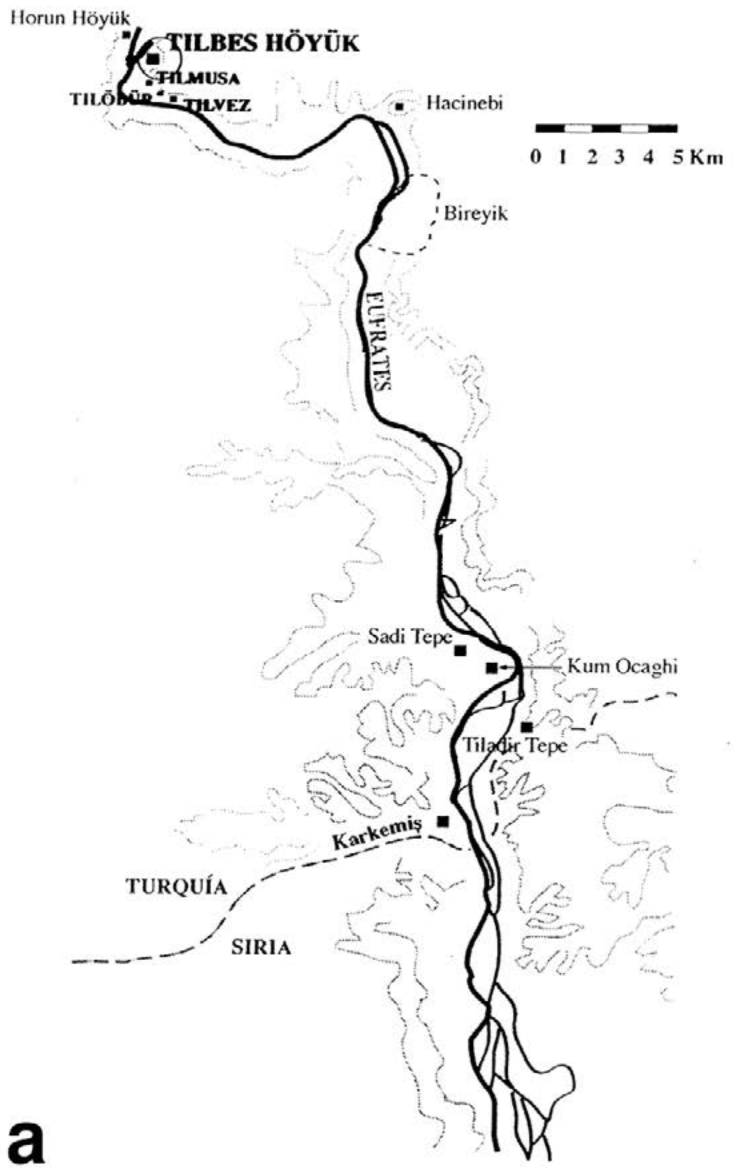
Off but close to the mound, a rescue excavation was carried out for two days by the Şanlıurfa Museum prior to our activities, in two rock-cut burial chambers east of the site that were discovered early in 1996 while taking materials for road construction from the conglomerate land 300m east of Meteler Village. Both tombs, dating back to the late Early Bronze Age, yielded an extensive bulk of artefacts, and the museum reported a total of 601 archaeological artefacts that were unearthed during the excavation. Among these artefacts, pottery consisting in vases, bowls, jars with hanging handles, bottles in addition to decorated animal bones, stone jewellery, stone beads and rings were reported to be discovered. Additionally, a copper stamp seal with a handle stands out among the burial location findings.

On the floor of a building at Tilvez Höyük, the remains, skull and long bones, of a male individual who suffered from some pathology that caused bodily deformities were found scattered; however, he was violently beaten and had bled to death (García Millán, pers. comm.). We know his fate thanks to the remains analysed at LaFUAM (UAM Forensic Laboratory). In Titriş Höyük there are remains of a massacre at the final moment of the occupation of the local EBA III (Erdal 2012).

In the same place as the find described, there was an associated local metallic wares from the late Early Bronze Age and a cylinder seal impression, characteristic of various cities, such as Tell Brak (Syrian Khabur) or Ebla/Tell Mardikh IIB 1–2 (northern Syria), in Mesopotamia from the 24th and 23rd centuries BC. This cylinder seal impression shows analogies with other artefacts found at Hama J4 or Amuq I (Charvát and Gil Fuensanta 2001: 565–68 fig. 3). This fragment, bearing an impression of a cylinder seal in the Ebla-palace manner (Mazzoni 1992: 25–26, 53, 103–104 and 241: pls IV, XI, XXXIII, dating to Syrian EBA IVA; Matthews 1997: 118–20, nos. 180–238, 136–137, n. 491, 145, 171–173, 183 and 190, dated to the 24th to 23rd century BC) bears out this affiliation, making Tilvez and neighbouring sites very likely candidates for an asset of the kings of Ebla.

This increase in the level of sediment discharge from the Euphrates is observed in the periodic floods recorded in Tilvez Höyük, whose effects can be perceived in the remains analysed. The archaeological site was submerged in Antiquity, after the described events, which demonstrates the drastic rise in the water level of the Euphrates since the end of the Early Bronze Age IV, which caused heavy flooding in nearby settlements. We deduce that bad harvests or unstable cycles in the course of nature induced not a few internal discomforts within the urban population, and perhaps we are facing some slight reflection of them. An environmental crisis at various times of the 3rd millennium in northern Mesopotamia has materialized in the geological and archaeological records. Tilvez Höyük offers a vision of a place as large in its origin as the nearby mound of Tilbes, but located at a lower level of the river, which led to periodic flooding of the Euphrates during various times in the 3rd millennium BC.

The excavations and surveys carried out by us on Tilvez/Eski Meteler in the first decade of the 21st century, Operations 4 to 9, show an important occupation of the initial phase of the Early Bronze Age, the EBA I, similar to that found in Tilbes Höyuk, depending on its ceramic and metallurgical production, perhaps with an unusual number due to its abundance of late-reserved slip jars typical of post-Uruk in our area of Birecik-Carchemish. In any case, there is also evidence of a strong flooding of the Euphrates River during this phase, and the subsequent abandonment of the site, at least for several centuries, until its re-occupation, as demonstrated by our Operations 1–4 in another sector



a

site	name	Early EBA	Middle EBA	Late EBA/ Early MBA	Late MB
1	Kalemaydanı Höyük			0.5	
2	Karaçalı Höyük			0.25	
10	Horum Höyük	8	8	8	
14	Tilbes Höyük	1	0.5	1	0.1
16	Tılmusa Höyük			0.5	
18	Near Zeugma 2	0.5	0.5		
21	Tepecik			0.5	
27	Near Hacınebi 1		0.5		
31	Tılöbür Höyük			1.44	
33	Surtepe Höyük	4		12	
34	Tılvez Höyük	3	1	3	
38	Kefri Höyük	0.5	0.5		
40	Büyük Tılmiyan Höyük	0.5		0.5	
44	Zeytinli Bahçe Höyük	0.8		0.2	0.2
49	Mağara Höyük	0.32		0.32	
50	Yarım Höyük/Tepe	0.3			
51	Mezraa Höyük	0.25	0.25	0.5	0.1
55	Danaoğlu H öyük			0.5	
56	Elifoğlu Höyük		0.5	0.5	
60	Şara Mezar Harabe		0.5		
63	Cısırın Höyük			0.5	
65	Şavi Höyük I		0.4	0.4	0.4
(65a)	Şavi Höyük II	0.1			
68	Near Akarçay 2		0.4		
71	Şaraga Höyük		0.5	0.5	
72	Akarçay Höyük			0.5	
82	Tıladir Tepe			12.2	
85	Carchemish	4	30	30	30

b

Fig. 7 – Main sites mentioned on the text (a). – Total interpreted extent of the Middle Euphrates mounds during the Early Bronze Age (b). – (a: drawing by Ben Claasz Coockson; b: after Wossink 2009: tab. 5.3).

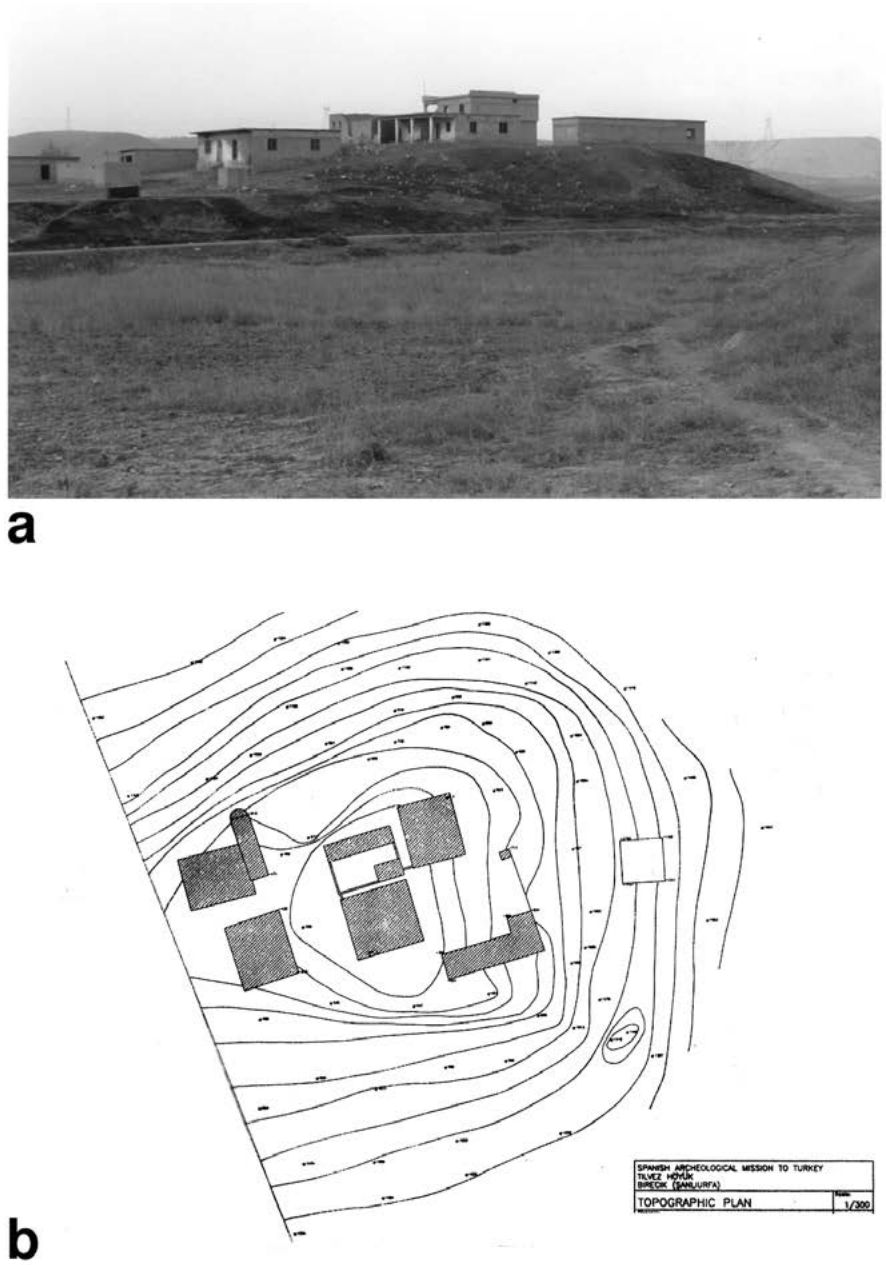


Fig. 8 – Tilvez Höyük, central and northern side of the mound (a). – Tilvez Höyük, central and northern side of the mound, topographic plan (b). – (a: photo Tilbes Project/MAET; b: drawing by architecture Studio Eloy Algorri).

of the *höyük*, at the end of the same 3rd millennium BC, during the local phases EB IIIb–EB IVa, as demonstrated by the walls in Operation 4 (Gil Fuensanta 2000: 253 fig. 8; Gil Fuensanta and Bucak 2000: 40 fot) (Fig. 8a–b). However, the abandonment of Eski Meteler during the EBA IVa contrasts with the livelihood and feverish activity of ceramic and metallurgical exchange during the EBA IVb as evidenced by the 'Great Building' of sector A2–A6 of Tilbes Höyük (Gil Fuensanta 2000: 252; Gil Fuensanta 2007).

Surtepe, in the vicinity of the mound of Tilvez (1km away), did have a wall that gives its name to the prehistoric occupation ('the mound of the city wall'). We deduce that the events of nearby Tilvez Höyük would affect the history of its neighbour; we even believe that both are two sectors of the same city during the period (Gil Fuensanta 2007). Tall mudbrick towers in the same area of the archaeological site prove their construction during Early Bronze Age I, the period before the collapse of the first cities (Gil Fuensanta *et al.* 2023: 50–53 fig. 16–17). There was no settlement during Early Bronze Age II (the age of the 'Transcaucasians') at the site, no remains characteristic of EBA III have been found, but the stratigraphic record indicates flourishing occupation during the Early Bronze Age III/IV transition, the final phase of the period, and there was silence for a long period afterwards. We cannot verify the existence of hostilities at the site during Akkadian times, although we do have characteristic late Early Bronze Age material from the northern sector of Surtepe.

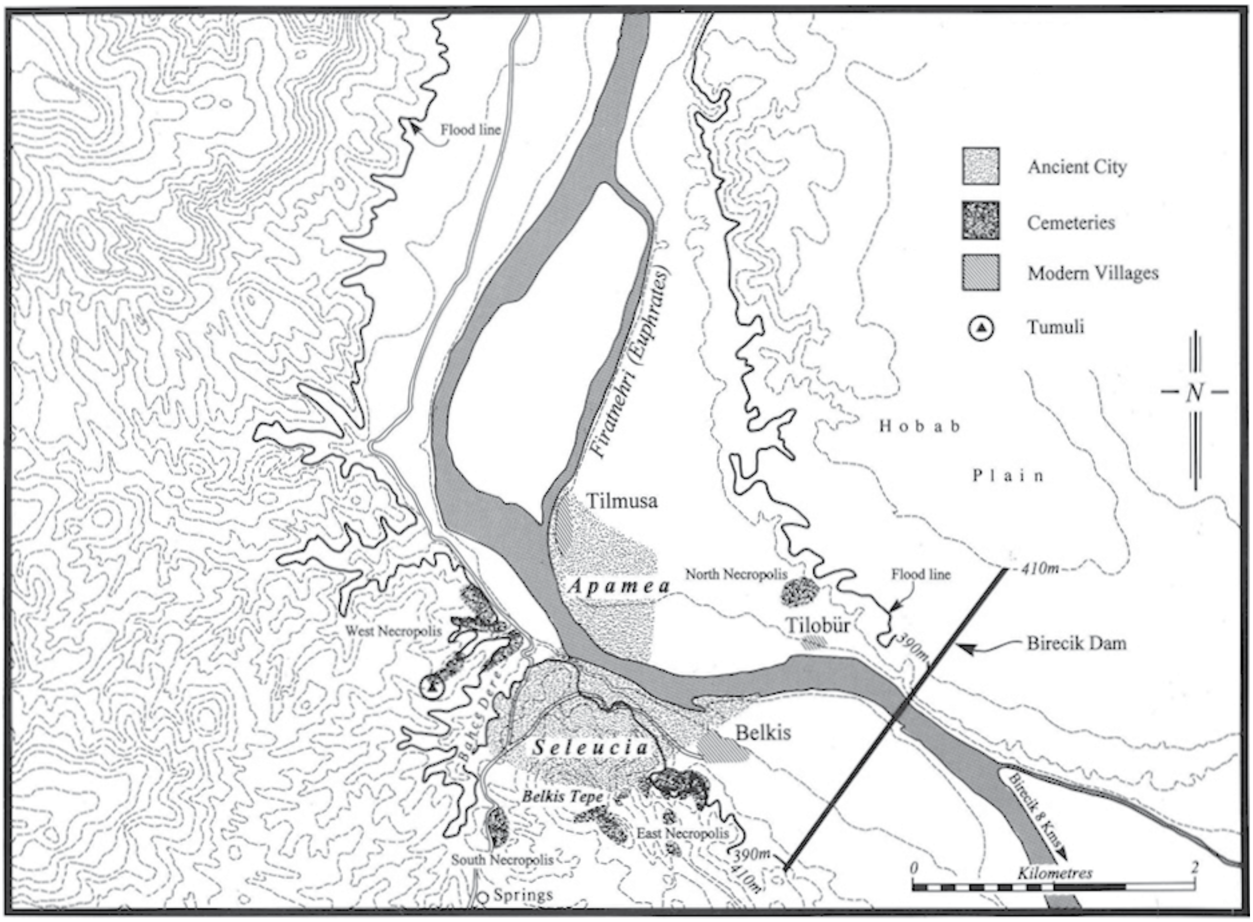


Fig. 9 – Tilöbür site in the vicinity of Tilmusa/Keskince. – (after Kennedy 1998: fig. 3).

A similar situation for the late Early Bronze Age is seen in Tilöbür Höyük, just south of Tilbes, not far from the ancient village of Keskince, and also submerged by the waters of the Birecik dam in the mid-2000s. In this place we were only able to verify *in situ* the existence of two archaeological periods, as reflected in our previous surface survey, as well as in a previous survey (Algaze et al. 1994): EBA IV/MBA I and Roman period (Fig. 9).

The excavations in Tilöbür Mound, located within the borders of Birecik district centre, were within the scope of the rescue excavations in the mounds buried under the Birecik and Carchemish dam lake areas. After our excavations, it was recognized that the most recent level of Tilöbür prior to the Roman period corresponds to an EBA III–IV phase, without showing some of the jars and shapes characteristic of the MBA I of the Middle-Upper Euphrates.

Tilöbür had little stratigraphic depth in its archaeological levels: in addition to an Imperial Roman occupation of the 2nd–3rd centuries AD, only two different occupation phases were present within the local EBA III/EBA IVA scheme. This is proof of two facts: 1) the great population expansion that the Birecik-Carchemish sector experienced during the period of the historical Akkadian imperial expansion (local EBA III in terms of archaeological chronology); 2) the existence of a rupture that causes a sharp and dramatic decrease in the number of occupied sites at some point in the late Early Bronze Age, an period that has been identified as one of great dryness in the Khabur River area (Weiss *et al.* 1993), but slightly later, sometime in the same late 3rd millennium, there was evidence of flooding at the river level in this area north of the modern city of Birecik (Kuzucuoglu *et al.* 2004: 204).

Conclusions

At the end of the 4th millennium in northern Mesopotamia there was an apparent depopulation of places. Cities as flourishing as Habuba Kabira-South on the Syrian Euphrates are abandoned. But on the other hand, other places in the south, such as Uruk/Warka itself, suffer internal changes in their urban layout. Several areas of Mesopotamia increase their population (for instance, in the Turkish Euphrates, Birecik-Carchemish subregion, bordering present-day Syria), even with a kind of local renaissance.

The Early Bronze Age of Northern Mesopotamia coincides with the process of the collapse of the post-

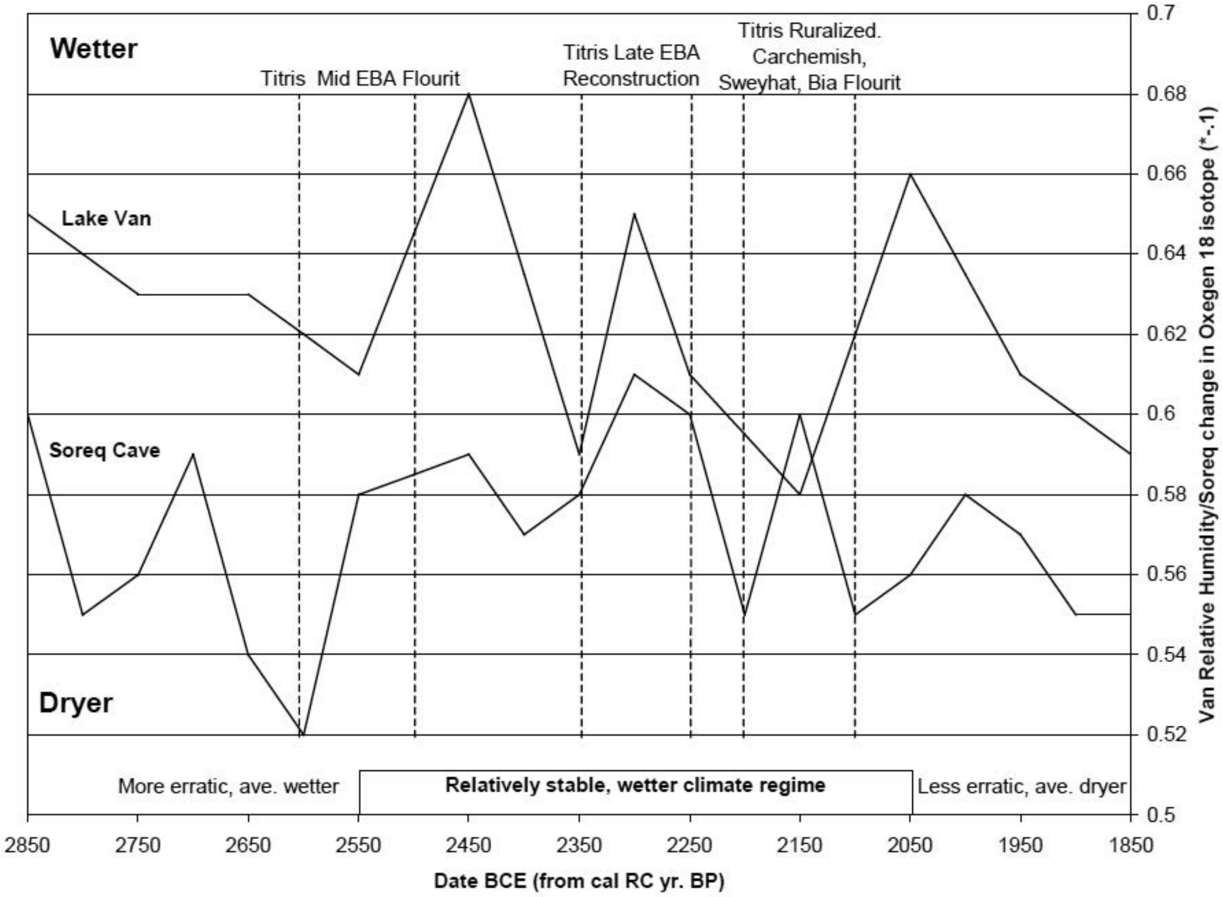


Fig. 10 – Correlation between climatic changes and urban changes at Titriș Höyük in relation with Lake Van relative humidity. – (after Algaze and Pournelle 2008: fig. 12).

Uruk system, the appearance of the phenomenon of the second urbanization and the subsequent access of that one. At the beginning of the Early Bronze Age (EBA) and at the end of the same period there are two peaks of extensive occupation of the territory north of the current modern city of Birecik. The buildings or installations with religious or ritual purposes found in Tilbes Höyük between the Early Bronze and Middle Bronze Age periods reflect a continuous and careful use of the site, in addition to a continuous care and reconstruction of several buildings with these characteristics (e.g., the sanctuaries of sector E4aE3E8), regardless of the predominant material culture in each period, whether of northern-Mesopotamian origin or of Anatolian origin as inferred mainly by the ceramics.

During the second half of the 3rd millennium BC there was a strong appearance of indigenous city-states into southeastern Turkey. The outlines and main traits of this Early Bronze Age city-state system which has been defined by previous surveys undertaken by Mehmet Özdogan's (Özdogan 1977) and Guillermo Algaze's teams (Algaze *et al.* 1994).

There was not a very pronounced break with the EBIV, but it was a very turbulent period throughout all of Mesopotamia; We must note the destruction and violence unleashed at the site of Titriş Höyük, replicated downstream in Tilvez/Meteler between EBA III and IV, which coincides with the large number of burials found in this place and the vicinity of this last site, prior to the MBA I. If there was a rejection by part of the occupants of Tilvez Höyük/Meteler during that time, this fact has no archaeological parallel in Tilbes Höyük, probably because the sanctuary's continuity.

On the collapse of the Early Bronze Age in northern Mesopotamia, alternative theories to those prehistorians who defend a collapse of the urban culture of the Early Bronze Age due to environmental problems need to be mentioned. According to this interpretation, in the wake of the political pressures of power, internal problems due to setbacks caused by bad harvests and environmental changes are masked. The climatic instability around the end of the 23rd century BC affected at some specific moments of the 3rd millennium the orography of the Euphrates (Weiss *et al.* 1993). In the Middle Turkish Euphrates drastic climatic events are recorded for various episodes of

Fig. 11 – Akkadian campaigns during the Naram-Sin period. – (after Liverani 1988: fig. 47).

the 3rd millennium BC, specifically between the 29th and 28th centuries BC and with important peaks during around 2440 and 2340 BC (Kuzucuoğlu 2007: 461).

The environmental change essentially produced an increase in the magnitude of flood and soil erosion. And these produced different effects according to the position of the mentioned places or the sector of the river (Kuzucuoglu *et al.* 2004: 199). In the case of Titriş Höyük, upstream of Tilbes Höyük, extreme episodic flood events occurred, in addition to a change in the rainfall pattern, which led to both periods of drought and other periods of flash floods (Wilkinson 1999). Flooding also occurred downstream in the Kurban Höyük sector (Algaze *et al.* 1994). This increase in the level of sediment discharge from the Euphrates is observed in the periodic floods recorded in Tilvez Höyük (Fig. 10).

The middle course of the Euphrates in Syria was no less dramatic from the environmental point of view. During the same period in the Syrian Middle Euphrates area, Tell Jerablus-Tahtani experienced an episodic increase of several metres at the river level and suffered from floods (Peltenburg *et al.* 1997).

The cause of these adverse conditions does not seem to be climatic in origin; rather, it appears an effect of land use practices by man (Wilkinson 1999). Higher flow variations during all Bronze Age periods in the Euphrates valley, increased erosion, or accelerated degradation in smaller catchments, are thus related to the Late Holocene climatic desiccation, but also to the increasing impact of human activities on the landscape during the 3rd and 2nd millennia BC (Kuzucuoglu *et al.* 2004: 204–209).

However, the very end of the mid Early Bronze Age and part of the late Early Bronze Age (EBA IV) periods of several of the Turkish Euphrates region sites covers also the time of the expansion of the Akkadian empire. Out of their bases on the lower course of the Euphrates and Tigris rivers, Akkadian imperial commanders directed their armies upstream both rivers. Ultimately, the imperial frontier was stabilized along the Taurus piedmont landscapes and on the Khabur river. Fortifying the age-old citadel of Tell Brak, the Akkadian administrators saw to it that the area between Khabur and Balikh was kept free of any possible enemy bases, as a 'no man's land', or *cordon sanitaire*. Their conquests resulted in making the Middle Euphrates a 'free-zone' frontier (Fig. 11).

The phase of Akkadian expansion on the Euphrates focuses us on a period in the history of southeastern Turkey with an abundance of trading activities and a specific increase of imports in our Birecik area (Holland 1994). Perhaps the exogenous elements of the Middle Bronze Age in Tilbes evoke one of the probable routes of post-Akkadian expansion across northern Mesopotamia, which would link these places in the Birecik-Carchemish area with the interior of Anatolia: an inner route into Anatolia, similar to that used by Old Assyrian merchants during Middle Bronze Age I, when Tilbes Höyük could probably have been a *wabartum* belonging to the kingdom of Urshum.

The high quality of the metal processed in the northern area of Birecik (specifically around the territory of the submerged town of Keskince in the year 2000) from the end of the 4th millennium to the Persian era during the Iron Age, as evidenced by the finds from Tilbes, Tilöbür, Eski Meteler or Surtepe, not only justify the existence of an internal Anatolian route that connects with the Middle Euphrates between Carchemish and Birecik, but the adaptation of foreigners to local religious ideas based on waters and fertility, since their syncretism is compatible with the Semitic deities (Akkadians or Assyrians, among others).

The evidence found in the different sanctuaries of Tilbes Höyük demonstrates a persistence of an old idea of fertility and worship of waters, which resists different historical ups and downs, and begins at least in the post-Uruk era in the Birecik-Carchemish area. We deduce, from the archaeological evidence unearthed through our campaigns, that there is an adaptation of the external cultures ‘in vogue’ during each period (post-Urukians, Akkadians, Old Assyrian merchants, Persians) to the ‘predominant local idea of the gods of the waters and the rebirth of fertility’.

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Agia Varvara-Almyras:
an Iron Age copper smelting site in Cyprus

Walter Fasnacht and Christina Peege

The Iron Age copper smelting site of Agia Varvara-Almyras in Cyprus has produced the first and only complete operational chain of ancient metal production excavated on the island. Innovative 3D modelling of features from the site It explores the potential of virtual archaeology when assessing and discussing a wide range of heterogeneous archaeological data.

Keywords: Cyprus, copper smelting, operational chain, 3D-retrodigitisation, Iron Age

Le site de fusion de cuivre de l'âge du fer d'Agia Varvara-Almyras à Chypre a produit la première et la seule chaîne opératoire complète de production de métaux fouillée sur l' île. La modélisation 3D innovante des caractéristiques du site explore le potentiel de l'archéologie virtuelle lors de l'évaluation et de la discussion d'un large éventail de données archéologiques hétérogènes.

Mots-clés : Chypre, fusion du cuivre, chaîne opératoire, rétronumérisation 3D, âge du Fer

Kıbrıs'taki Agia Varvara-Almyras Demir Çağı bakır eritme sahası, adada kazısı yapılan ilk ve tek eksiksiz antik metal üretim zincirini ortaya çıkarmıştır. Alandaki özelliklerin yenilikçi 3D modellemesi Çok çeşitli heterojen arkeolojik verileri değerlendirirken ve tartışırken sanal arkeolojinin potansiyelini araştırıyor.

Anahtar Kelimeler: Kıbrıs, bakır eritme, operasyonel zincir, 3 boyutlu retrodigitizasyon, Demir Çağı

The Iron Age copper smelting site of Agia Varvara-Almyras in Cyprus is situated 20 km south of Lefkosia and was discovered in 1982 by Walter Fasnacht (Fasnacht *et al.* 1989). Almyras has been under regular excavations from 1988 to 2000. It represents the first and only complete operational chain of ancient metal production excavated in Cyprus (Figs 1; 2a). All finds, from the mine, the ore, the slag and matte, to raw copper and the refined copper metal, date from Cypro-Archaic II to Cypro-Hellenistic II, i.e. from roughly 600 to 150 BC. Nine firing units were found in situ, namely smelting furnaces, two ore roasting pits and an oven supposedly for food processing (Figs 2b; 3). Analysis of excavated finds includes element and trace element analysis as well as electron microscope analysis on thin sections of all geological and metallurgical material involved, lead isotope and osmium isotope analysis of copper and iron, geomagnetic dating of furnace installations, wood species identification and radiocarbon dating of charcoal. As shown by the results of those analyses, all components of the copper production at Almyras are local. There is no need to import anything: From water and clay of the adjacent river, from wood for charcoal and ore to flux, everything is sourced from the immediate surroundings of the site.

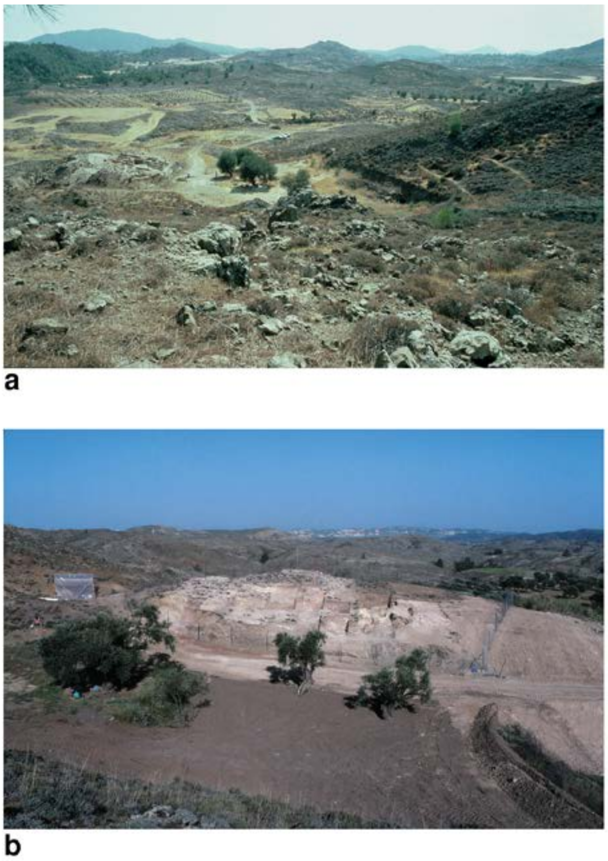

Fig. 1 – The site of Agia Varvara-Almyras: Smelting site with furnaces on the left, mining ores on the right of the olive trees, looking South (a). – View of the smelting site of Almyras, looking East (b). – (Images: Almyras Excavation Project).

A framework for testing scientific results or modelling archaeological data into a holistic archaeological landscape was an additional major long-term desideratum. An innovative 3D modelling based on the retrodigitization of archaeological data was proposed by

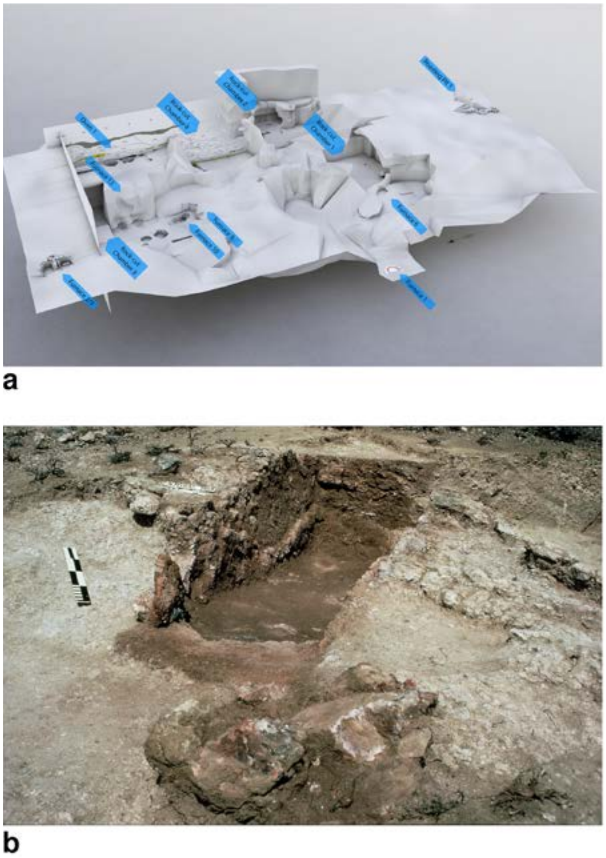

Fig. 2 – Retrodigitization of the site and archaeological installations (a). – Roasting pit No. 1, cut into the rock, Cypro-Hellenistic II Period (b). – (Images: Almyras Excavation Project).

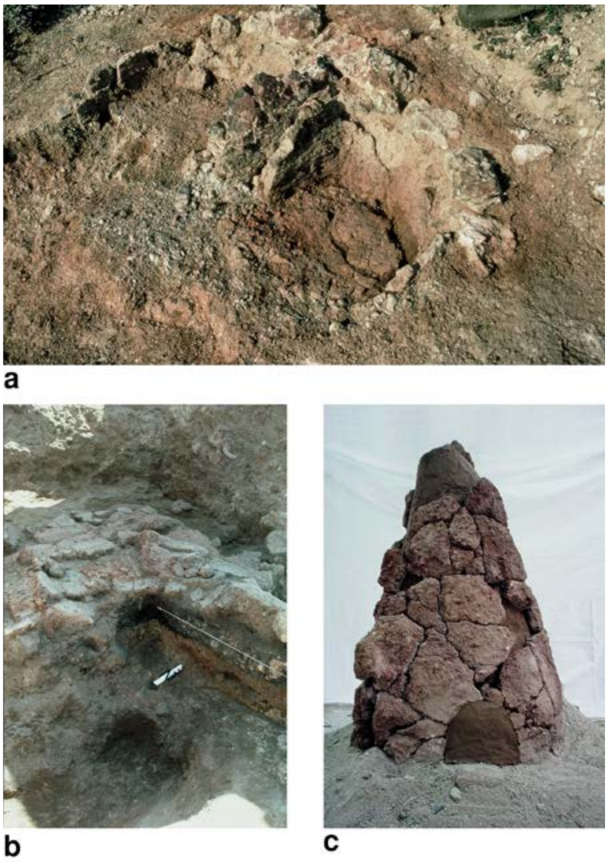

Fig. 3 – A double furnace, Cypro-Archaic Period; the two chambers are equal and do not show signs of different stages of process (a). – Smelting furnace No. 8, Cypro-Classical Period, with furnace No. 10 below; furnace No. 8 was destroyed and covered with a big rock, i.e. taken out of sight (b). Original fragments of furnace No 8, rebuilt over a core of clay; with only one air inlet (c). – (Images: Almyras Excavation Project).

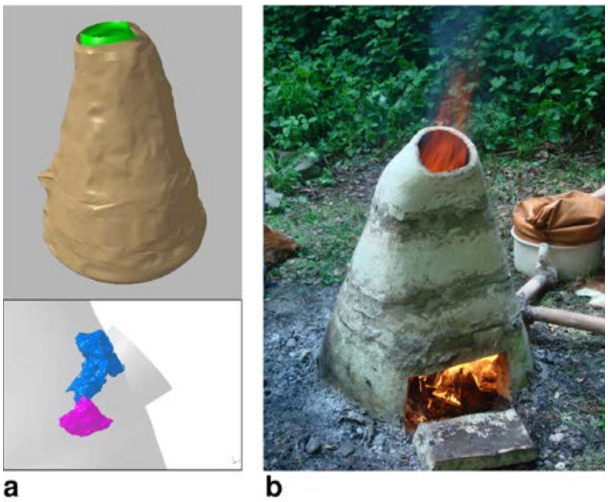

Fig. 4 – Top: 3D-Reconstruction of Furnace No. 8, green: inner surface, brown: outer surface; bottom: 3D-reconstruction of the position of the tuyere into Furnace No. 8 (a). – Experimental reconstruction and operation of Furnace No. 8 using pot-bellows as found in Cyprus (b). – (Images: Almyras Excavation Project).

Christina Peege in her 2018 PhD on the copper smelting site (Peege 2018). It explores the potential of virtual archaeology when assessing and discussing a wide range of heterogeneous archaeological data. Although the published model primarily served reconstructive purposes, its computer-based approach can also be used as a point of departure for modelling and testing hypotheses linked to ore and copper processing (Fig. 4).

Almyras is embedded in a series of Iron Age, Roman and Medieval copper production sites in the valleys reaching into the Troodos mountains from the Mesaoria plain south of Lefkosia, and many sites discovered in our surveys await further investigation (Fasnacht and Georgiou 2006; Fasnacht *et al.* 1997).

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Arsenic at the Chrysokamino smelting site

Philip P. Betancourt

Chrysokamino is a copper smelting site that flourished in the third millennium BC on the coast in northeast Crete. The workers smelted copper ore imported from the Cycladic islands. Because the ore included traces of arsenic, the resulting copper included small amounts of this metal as well. Arsenic was also a deliberate addition to copper to create an arsenical alloy because pure copper does not create good casts using open moulds in the presence of oxygen. The amount of natural arsenic in these suggests using 2% arsenic as a guide to distinguish natural impurities from deliberate additions in Bronze Age arsenical copper.

Keywords: Crete, Minoan, copper, smelting, arsenic, arsenical, metallurgy, Chrysokamino

Chrysokamino est une fonderie de cuivre qui a prospéré au troisième millénaire avant J.-C. sur la côte du nord-est de la Crète. Les ouvriers fondaient du minerai de cuivre importé des îles Cycladiques. Étant donné que le minerai contenait des traces d'arsenic, le cuivre obtenu contenait également de petites quantités de ce métal. L'arsenic était également un ajout délibéré au cuivre pour créer un alliage d'arsenic, car le cuivre pur ne crée pas de bons moulages en utilisant des moules ouverts en présence d'oxygène. La quantité d'arsenic naturel qu'ils contiennent suggère d'utiliser 2% d'arsenic comme guide pour distinguer les impuretés naturelles des ajouts délibérés dans le cuivre arsenical de l'âge du Bronze.

Mots-clés : Crète, Minoenne, cuivre, fusion, arsenic, métallurgie, Chrysokamino

Chrysokamino, Girit'in kuzeydoğusundaki kıyıda MÖ üçüncü binyılda gelişen bir bakır eritme yeridir. İşçiler Kiklad adalarından ithal edilen bakır cevherini eritmişlerdir. Cevher eser miktarda arsenik içerdiğinden, elde edilen bakır da az miktarda bu metali içeriyordu. Arsenik ayrıca arsenik alaşımı oluşturmak için bakıra kasıtlı olarak eklenmiştir çünkü saf bakır, oksijen varlığında açık kalıplar kullanılarak iyi dökümler oluşturmaz. Bunlardaki doğal arsenik miktarı, Bronz Çağı arsenik bakırındaki doğal safsızlıkları kasıtlı ilavelerden ayırt etmek için %2 arseniğin bir kılavuz olarak kullanılmasını önermektedir.

Anahtar Kelimeler: Girit, Minos, bakır, izabe, arsenik, arsenik, metalurji, Chrysokamino

Although arsenic has been a serious subject for study ever since it was first recognized as a major component in early copper metallurgy, its serious examination has been hampered by several problems. The arsenic content of ancient copper artefacts exists in a continuous series from traces that must be accidental to amounts that are certainly deliberate, but the exact point at which one should assign a deliberate alloy is difficult to judge from finished artefacts because of the practice of re-melting old tools. Particularly in the Aegean, where re-melting was especially common, the nature of an arsenical copper alloy has been problematical because it is difficult to decide the estimated point at which accidental arsenical inclusion should be replaced by deliberate alloying. Some evidence in this matter is available from the smelting site at Chrysokamino, in northeast Crete where ores containing small amounts of arsenic were smelted during the third millennium BC.

Chrysokamino is a small archaeological site that was in use from ca. 4000 BC to the late second millennium BC. It is located on the northeast coast of the island of Crete, at the eastern side of the Gulf of Mirabello. The site is a small promontory on a cliff above the sea where copper smelting was practised intermittently for several hundred years during the Early Bronze Age. Chrysokamino was excavated and studied under an American excavation permit issued by the Greek government (Betancourt 2006).

At the site, the ground is covered with a low slag pile composed of fragments of red clay furnace chimney pieces, black glassy slag, and some white local stones. Almost no vegetation grows here. The smelting used furnace chimneys made with clay that was tempered by adding the residue from harvesting grains (chaff), which would only have been available in the fall of the year, providing an indication of the short time that this seasonal activity occurred. The time of year may have been chosen because this is a very windy season in this part of the Aegean.

The smelting site was set up at the top of the sheer cliff overlooking the sea. Because the smelting site has slightly higher ground both to its east and its west, the tiny valley acts as a funnel channeling the north winds. The site consists of a large pile of black slag, broken into pieces that are mostly under 5cm in size, along with red chimney fragments. The chimney fragments have holes that were made in their sides while the clay was still soft. Pottery found in the slag pile establishes its date,

from Final Neolithic (*c.* 3000–2700 BC) to Early Minoan III pottery (*c.* 2200–2000 BC).

Chimney fragments accounted for most of the pottery found in the slag pile. They were fragments of the cylindrical tubes placed over the furnaces. They were made of coarse local clay as cylindrical tubes that tapered slightly at the top. The tubes were ventilated by the placement of holes every few centimetres in the clay. Their use as chimneys is proved by the fact that their interiors were covered with a glassy deposit from the cooling fumes that passed through them from the furnaces below. These chimneys had been placed over the small bowl furnaces excavated in the ground. A small wind break of apsidal form was constructed over the slag pile by driving posts into the ground to accommodate a hearth (Fig. 1).

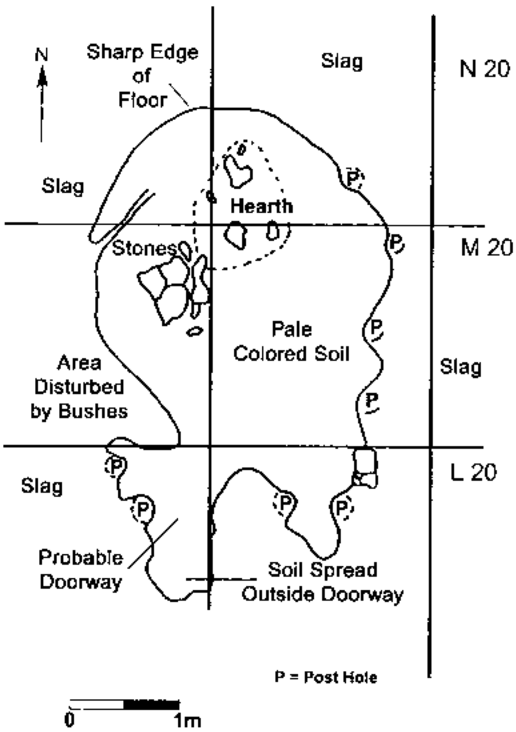

Fig. 1 – Plan of the small hut or windbreak constructed on the slag pile at Chrysokamino, Crete, to allow a hearth on the windswept hill where the workshop was located. – (Drawing: Philip Betancourt).

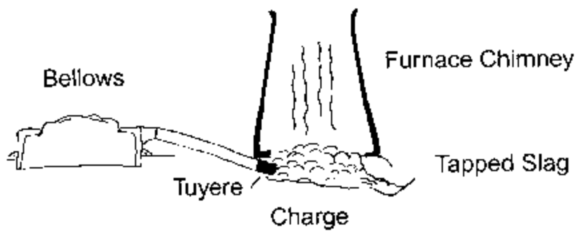

Fig. 2 – Reconstruction of the copper smelting process at Chrysokamino, Crete, using bellows to aid the draft. – (Drawing: Philip Betancourt).

Fig. 3 – Reconstruction of a Minoan workman using a bellows at Chrysokamino. – (Drawing: Lyla Pinch Brock).

A reconstruction of the smelting process used at Chrysokamino is based on the evidence of the broken pieces of slag and furnaces (Fig. 2). The materials for the operation (copper ore, fuel consisting of the remains from olive oil presses, and iron ore as a flux) were put into small bowl furnaces excavated into the ground. Each furnace would have been only about 30–40cm across. The fuel was set on fire, and the temperature was raised, presumably with the aid of man-made draft created by blowpipes. At the end of the site's history, *c.* 2000 BC, the intake of air into the furnaces was increased by the use of bellows.

Many fragments of the bellows were discovered. Their date is Early Minoan III, from the final phase of the workshop (Fig. 3). They are the earliest known metallurgical bellows from the Aegean. They were made as basins with straight sides and a spout at the bottom of the wall. The spout would have accommodated a long cylindrical blowpipe with a clay tuyère at its end where it entered the furnace. A large opening was cut into the flat base of the ceramic shape used as a bellows to accommodate a leather pumping device and its wooden frame. For use, each bellows was set into the ground with the rim down and locked into the soil with clay and the clay pumping mechanism upward, where it could be manipulated to bring air into the device through flaps in the leather and force it out through the blowpipe and into the furnace. In practice, these early bellows were not 100 percent effective. The fragments show that some of the air was drawn back accidentally through the pipe where it burned the interior of the bellows and turned it black.

These bellows will have replaced the simpler blowpipes of previous times. They produced a temperature that was sufficient to smelt the copper ore and produce a flow of copper that exited through the side of the furnace. It also produced abundant amounts of black

glassy slag, which sometimes contained small copper prills that were collected and analysed to discover their composition. The cylindrical chimneys with holes in their sides were placed over the furnaces (Bassiakos and Catapotis 2006; Stos and Gale 2006). The ore consisted of malachite and azurite, both of which are easy to smelt. The matrix for these ores was iron oxide, which would have provided a fluxing agent. The ores were imported from the Cyclades, from the region of Kythnos and Lavrion (Bassiakos and Catapotis 2006; Stos and Gale 2006). Iron ore for the flux and the fuel were both available locally, but part of the iron ore used as the flux was included along with the copper ore, so very little additional material would have been required.

The smelted copper must have been a very valuable material. The furnaces were tapped so that the melted copper would run out, but the small amounts left in the slag were also carefully retrieved. The slag fragments in the waste pile were all in very small pieces because they had been broken to remove any copper included as prills.

The final phase of the smelting operation survived most completely. By this time the slag pile had accumulated to a depth of over 40cm. A small shelter was constructed on the slag pile where a hearth was constructed. The shelter (Fig. 1) was built of vertical posts sunk into the slag pile, with branches of hides woven into the posts to create a windbreak from the fierce wind that blows on this high cliffside during the fall. The windbreak would have been necessary for the fire inside the shelter. A floor was made by covering the rough floor of the shelter on the slag pile with local soil. The small shelter was surely used to prepare the food for the workers at the smelting workshop. Several ceramic fragments of bowls were found in the small shelter, and they were analysed by gas chromatography to discover the contents (Beeston et al. 2006). To our surprise, several of them contained medicinal ingredients including camphor, fennel, and resinated wine. The conclusion of the analysts was that the shelter had been manufacturing and storing medicines, especially the types used for skin lesions, which is the most common early symptom of arsenic poisoning.

Two different studies were made to discover the composition of the copper smelted at the site (Ferrence and Swan 2006; Bassiakos 2006, 394–395 table B2). Both of them used copper prills collected from the slag for examination. The site is, therefore, of interest as an example of the arsenic content of copper from a primary smelting site rather than from a final manufactured tool where the use of earlier re-melted scrap cannot be ruled out as a source of the additives. In order to determine the differences between arsenic included in the corrosion and arsenic included in the copper, the two studies analysed different parts of the prills.

The Delaware analysis was by Susan Ferrence and Charles Swann. It was conducted on 13 copper prills discovered as inclusions in the slag. It was performed by PIXE, which is proton-induced X-ray emission spectroscopy at the Bartol Research Institute at the University of Delaware. The study tested single spots where the prill was very tiny and three spots that were averaged where the prill was large enough to have three points each 100 micrometers apart. The results showed that the amount of arsenic varied from 0.03% to 3.42% with the average being 0.72%. The analyses were run on the surface of corroded prills.

The analysis in Athens was conducted by Yannis Bassiakos, at the Laboratory of Archaeometry, Institute of Materials Science, N.C.S.R. Democritos, Hagia Paraskevi, Athens, Greece. It consisted of analysis by SEM/EDAX on copper prills similar to those used for the examination by Ferrence and Swann. A difference is that the prills were sawed and mounted, so that the result is for clean copper rather than the corrosion. Of the 49 samples examined, 22 contained arsenic. None was detected in the other samples. The amount of arsenic ranged from zero to 26%, with an average of 5.51% where it was detected, but with a number of places where it was not found. The average amount in the 49 prills was 1.9%. Both studies showed that the amount of arsenic at the microscopic level is highly variable from prill to prill. The amount of arsenic present in the copper itself was shown to be larger than that in the corrosion products, suggesting that it was depleted in the corroded areas. With a highly variable content and an average of 1.9%, the amount of naturally present arsenic in this smelted copper, the results are of great interest in distinguishing accidental from deliberate arsenic percentages.

The conclusions from these two studies are very important. The differences between the amount of arsenic in the corrosion and in the uncorroded copper demonstrates that the toxic metal is easily lost to the atmosphere where it can be ingested by breathing, helping to explain its serious health hazard. It can build up in the human body over time, which is probably why its use was abandoned and replaced by tin. The presence of almost 2% arsenic in the unalloyed copper at the smelting stage provides a guide for estimating the difference between tools made of unalloyed copper with accidental arsenic contents and artefacts with arsenic added later to produce an alloy.

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Preliminary report on the archaeological and archaeometallurgical analysis of a Late Bronze Age hoard from Vatta-Telekoldal-dűlő (Northeast Hungary)

Béla Török, Péter Barkóczy, Nikolett Kovács and Eszter Fejér

In 2020, during a metal-detector survey, part of a Late Bronze Age metal hoard was discovered in Vatta-Telekoldal-dűlő (NE Hungary). Although the hoard had been heavily disturbed by agricultural activities, 14 objects were unearthed *in situ*. The assemblage consists mostly of broken artefacts (axes, sickles, rings, ingots etc.). Several artefacts were selected for chemical and metallographic analyses. By using a portable XRF spectrometer, initial insights have been gained about the copper alloys used for the objects. As regards the chemical composition of the finds examined, mainly the variation in the tin content was remarkable, and this also allowed the pieces to be well grouped. However, interesting correlations were found between the concentrations of tin and other constituents (lead, arsenic, antimony, and silver). Metallographic analysis with an optical microscope and SEM-EDS provide useful information about the microstructure of the inner parts of the cut samples, and possible manufacturing lines were identifiable as well. The combined results from the archaeometallurgical and use-wear analyses indicate a diverse hoard composition in which both raw metal, miscast and used artefacts played a role.

Keywords: Bronze hoard, Late Bronze Age, Carpathian Basin, ED-XRF, microscopy

En 2020, lors d'une étude au détecteur de métaux, une partie d'un dépôt d'objets métalliques du Bronze final a été découverte à Vatta-Telekoldal-dűlő (nord-est de la Hongrie). Bien que le dépôt ait été fortement perturbé par les activités agricoles, 14 objets ont été mis au jour sur place. L'assemblage est constitué principalement d'objets brisés (haches, faucilles, anneaux, lingots, etc.). Plusieurs artefacts ont été sélectionnés pour des analyses chimiques et métallographiques. En utilisant un spectromètre XRF portable, des premières informations ont été obtenues sur les alliages de cuivre utilisés pour les objets. En ce qui concerne la composition chimique des trouvailles examinées, c'est surtout la variation de la teneur en étain qui a été remarquable, ce qui a également permis de bien regrouper les pièces. Cependant, des corrélations intéressantes ont été trouvées entre les concentrations d'étain et d'autres constituants (plomb, arsenic, antimoine et argent). L'analyse métallographique avec un microscope optique et SEM-EDS fournit des informations utiles sur la microstructure des parties internes des échantillons coupés et les lignes de fabrication possibles ont également été identifiables. Les résultats combinés des analyses archéométallurgiques et tracéologiques indiquent une composition diversifiée du dépôt dans laquelle le métal brut, les objets mal coulés et les objets usagés ont joué un rôle.

Mots-clés : dépôt de bronze, Bronze final, bassin des Carpates, ED-XRF, microscopie

2020 yılında, bir metal dedektörü araştırması sırasında, Vatta-Telekoldal-dűlő'de (KD Macaristan) bir Geç Tunç Çağı metal istifinin bir kısmı keşfedildi. İstifin, tarımsal faaliyetler nedeniyle büyük ölçüde tahrip edilmiş olmasına rağmen, 14 nesne in situ olarak ortaya çıkarılmıştır. Buluntu topluluğu çoğunlukla kırık eserlerden (baltalar, oraklar, yüzükler, külçeler vb.) oluşmaktadır. Kimyasal ve metalografik analizler için birkaç eser seçilmiştir. Taşınabilir bir XRF spektrometresi kullanılarak, nesneler için kullanılan bakır alaşımları hakkında ilk bilgiler elde edilmiştir. İncelenen buluntuların kimyasal bileşimine gelince, esas olarak kalay içeriğindeki çeşitlilik dikkat çekiciydi ve bu da parçaların iyi bir şekilde gruplandırılmasını sağladı. Bununla birlikte, kalay ve diğer bileşenlerin (kurşun, arsenik, antimon ve gümüş) konsantrasyonları arasında ilginç korelasyonlar bulunmuştur. Optik mikroskop ve SEM-EDS ile yapılan metalografik analizler, kesilmiş numunelerin iç kısımlarının mikro yapısı hakkında faydalı bilgiler sağlamış ve olası üretim hatları da tespit edilebilmiştir. Arkeometalurjik ve kullanım-aşınma analizlerinden elde edilen birleşik sonuçlar, hem ham metalin, hem yanlış dökümün hem de kullanılmış eserlerin rol oynadığı çeşitli bir istif bileşimine işaret etmektedir.

Anahtar Kelimeler: Bronz hazinesi, Geç Tunç Çağı, Karpat Havzası, ED-XRF, mikroskopi

Introduction

Vatta-Telekoldal-dűlő is located in Northeast Hungary, in the Bükkalja region, which stands between the North Hungarian Mountains and the Great Hungarian Plain. The area offers favourable conditions for settlement, rich water sources, arable lands and various raw materials. Natural resources have been exploited since prehistory and are utilized also in modern times.

The company called today MVM Mátra Energia Zrt. operates the Mátra Power Plant in northern Hungary, whose lignite fuel supply is provided by two open-pit mines: one established in Visonta in 1965 and another

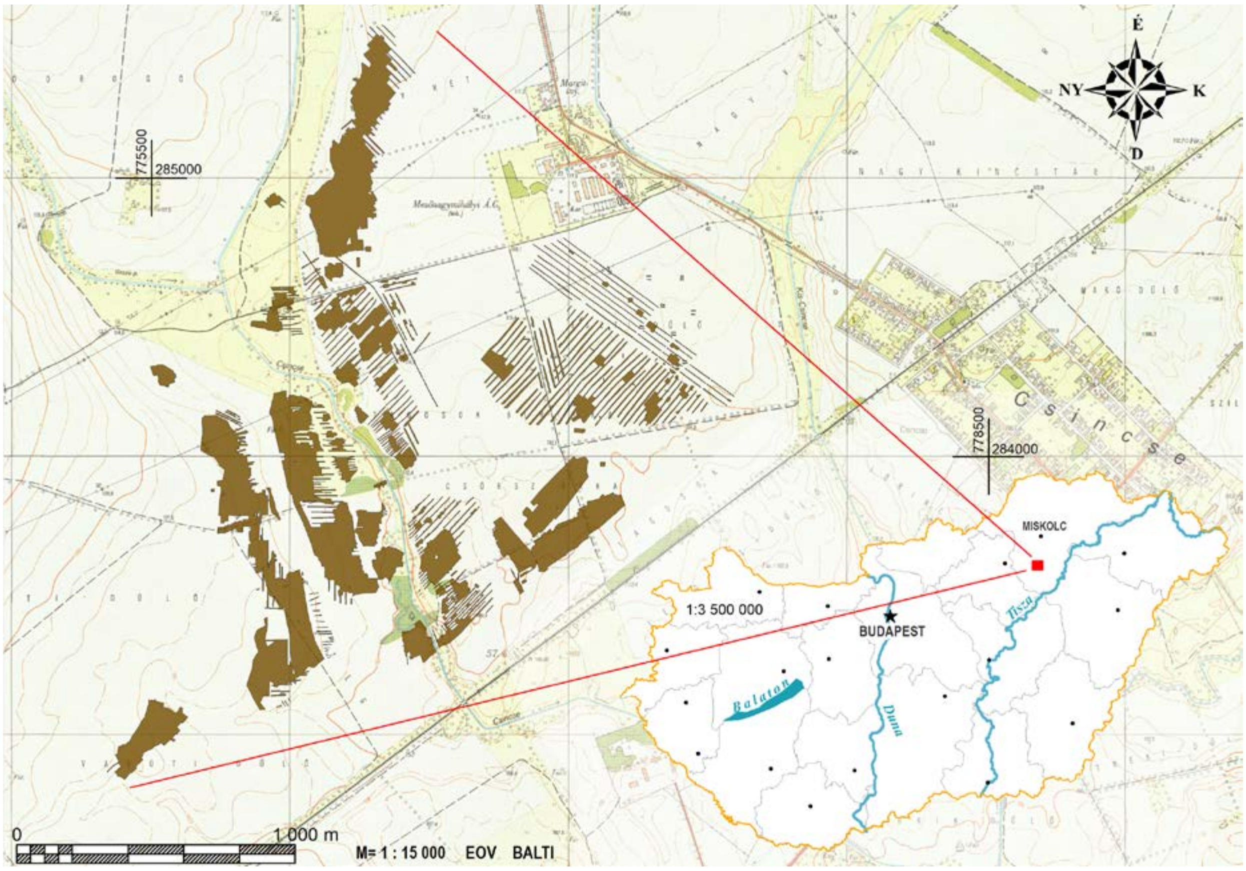

Fig. 1 – Map of Hungary and the archaeological sites at Bükkábrány. – (Map: Dániel Kiss).

one opened 20 years later in Bükkábrány, near Vatta (Fig. 1). Archaeologists of the Herman Ottó Museum (Miskolc) have been conducting excavations in the territory of the lignite mine in Bükkábrány since 2007. As the complete area scheduled for mining must be archaeologically surveyed and, where necessary, excavated, they had a unique opportunity to unearth complete sites, regardless of whether they extend over a couple of square meters or several hectares. Until now more than 600 000m^2 have been excavated. The current mining activity changes the landscape significantly. Therefore the task of the archaeologists is not solely the rescue excavation, but it includes also the exploration and detailed documentation of the entire depositional structures, which requires several months of work every year.

The territory of the mine stretches across the former valleys of the Csincse and Geszti streams at the foothills of the Bükk Mountains. This area has a roughly 7000 years-long settlement history, ranging from the Middle Neolithic to the Middle Ages, testifying to ideal environmental conditions. Nearly 20 sites have been identified and reported by archaeologists over the past years (e.g., Faragó *et al.* 2015; Kalli and Tutkovics 2016; 2017; Füzesi *et al.* 2021; Kovács and Németh 2022).

In the fall of 2020, the archaeologists of the Herman Ottó Museum carried out excavations at the site of Vatta-Telekoldal-dűlő, because the mining company started to prepare the installation of four drainage wells. Two of these zones yielded no archaeological material, but the other two areas were found to be positive regarding prehistoric finds. Altogether 554m^2 were excavated and 11 features were identified in an area of 350m^2. They represent the Neolithic (Linear Pottery Culture), Copper Age, Late Bronze Age, Early Iron Age and the Sarmatian period.

In addition to the excavations, István Bacskai and Pelta Bt. conducted a systematic metal detector survey in the investigated area. Several single metal finds were collected (e.g., sickles, pins, ingot fragments), but south of the well 11D/20 a Late Bronze Age hoard was also identified. Over 30 artefacts were provisionally connected to the assemblage. Despite the large extent of the territory investigated, this is only the second documented hoard in the vicinity of Bükkábrány. The first one was discovered at a distance of approximately 2km (Kalli 2017).

The hoard – and further bronze artefacts

The remains of the Late Bronze Age (LBA) hoard were discovered partly *in situ*, in a heavily destroyed, non-diagnostic ceramic vessel, which contained 14 intentionally damaged, fragmented bronze artefacts.

Fig. 2 – The *in situ* bronze artefacts of the hoard from Vatta-Telekoldal-dűlő and the finds collected from the vicinity, possibly belonging to the hoard. – (Photo: Nikolett Kovács).

The core assemblage consists of several tools, including fragments of five tanged sickles, two axes, and one saw, as well as a ring-shaped attachment of a cauldron's handle, a fragment of a decorated ring, an unidentified hemispheric object (presumably compressed remains of multiple objects), a piece of a massive ring (probably a ring-shaped ingot), a melted bronze item, and a fragment of a raw copper ingot.

As only the lower part of the vessel was discovered, it is plausible to assume that further bronze artefacts could have been part of the deposited assemblage. In the 5 × 5m excavation area opened directly around the hoard, two additional sickle fragments and a very small rectangular bronze object were unearthed, while within a radius of 200m, 24 further bronze artefacts were collected, which could have also belonged to the original hoard (Fig. 2). Some of these stray fragments fit together, while others match a fragment discovered in the vessel. These stray finds include fragments of four socketed axes, nine tanged sickles, a hemispheric object (very similar to the one from the *in situ* assemblage) and a copper ingot.

The systematic metal detector survey covered a large area in the vicinity of the hoard and yielded 60 additional metal artefacts from various prehistoric and historic periods. Although some of these finds can be of Bronze Age origin, it is highly hypothetical to connect them to the discussed assemblage, since other Middle and Late Bronze Age features have been also revealed in the area (see above and P. Fischl *et al.* 2020: 52–58).

Preliminary evaluation of the assemblage

Despite their spatial proximity, the presented artefacts can not be considered all as one closed assemblage; the *in situ* and stray finds must be investigated separately. The ceramic vessel containing the finds was not chronologically diagnostic, but the bronze items provide a clue for dating the assemblage. Most of the fragments in the hoard represent common LBA types, which had been produced in the Carpathian Basin for a longer period. The tanged sickles and the socketed axe have analogies both from the early and the younger Urnfield Period, although quantitative tendencies rather suggest the younger date (Dietrich 2021; Fejér 2020; Jahn 2013; Kemenczei 1984; Mozsolics 1985; Mozsolics 2000; Novotná 1970). The ring-shaped handle attachment (*Kreuzattasche*) belonged to a cauldron, which usually appears in the hoards of the younger Urnfield Period in the region (Patay 1990). These observations indicate that the hoard was not deposited before the HaA2–HaB1 period. The stray bronze artefacts can be roughly dated to the same period. Some fragments represent general LBA types, but among the sickles and axes characteristic types of the younger Urnfield Period can be also identified.

For a better understanding of the reasons behind the hoarding phenomenon, besides typochronological studies, the analysis of the condition, manufacturing process and use-wear traces of the deposited artefacts is also necessary. Regarding these questions, the *in situ* and stray finds show similar patterns. The analysis of the objects has revealed that most of the tools were definitely prepared for use: traces of hammering (sharpening and reinforcing) and possible whetting were observed on the blades. On some other objects, worn-out surfaces indicate their former use. Most of the tools were deposited after usage, although not in a heavily used condition. During the autopsy of the objects, several minor casting defects were also observed, which, however, did not significantly affect the usability of the tools. There was only one case where the defect might have severely weakened the tool (a sickle) and its durability.

Most of the artefacts (both *in situ* and stray finds) were unearthed in fragmented condition. In many cases, obvious recent damages are visible on the finds, which were most probably caused by agricultural activities of the past decades. In cases of the matching fragments, it can be demonstrated that they got separated due to post-depositional processes. However, deliberate prehistoric fragmentation can be also evidenced: on many objects chisel or axe blade marks testify to an intentional destruction practice.

Considering all these aspects, the preliminary investigation suggests that the *in situ* and stray finds have similar characteristics, which strengthens the assumption that they might have belonged together. This hoard consisted predominantly of tools but included also raw materials and some other objects. The artefacts were deposited in a deliberately fragmented state, mostly in used, but not heavily used, heterogeneous conditions.

Archaeometric investigation

Chemical analysis and metallographic examination of numerous objects of the hoard have been carried out by the experts of the Archaeometallurgical Research Group of the University of Miskolc (ARGUM). The primary aims of the examination were to observe the chemical composition and microstructure of each object (focusing on differences and similarities) and to determine the production technology of the artefacts. However, further questions have arisen regarding the hoard, for instance: How many types of raw material can be distinguished? Are there any connections between the raw materials and the different artefact types?

In this paper, the results of the examinations of two socketed axes and three sickle fragments belonging possibly to the described assemblage, and some pieces of raw material (an ingot and three pieces of lumps) collected from the broader vicinity, are presented and discussed as typical examples of the investigation. The examined objects can be seen in Figure 3, the sampling locations are marked with red lines.

The objects and the cut samples have been examined by energy-dispersive X-ray fluorescence (ED-XRF). An Oxford Instrument X-MET8000 portable XRF spectrometer (X-ray beam parameters: 50kV/30μA, Rh anode, Silicon Drift Detector) has been used. Two calibration methods were employed for the measurements. The Alloy FP method is developed for the analysis of the most common elements found in alloys. The Alloy LE FP method is similar to Alloy FP but also includes light elements, such as, for example, Mg, Al and Si. The concentration range for each element goes from 0% to 100% in all three cases. Fundamental parameter (FP) methods use a complex mathematical analysis of X-ray fluorescence to calculate the concentration of elements. For metals with inherently unknown composition, such as historical finds, this method is highly suitable and recommended. In all cases, the tests were performed with a measurement time of 30 seconds. In this paper, only the averages of the results measured by the Alloy FP method are reported. We distinguished between the averages of the values measured on the surface of the object and on the surface of the sample cut from it. Technically, the results of the Alloy LE FP method have informed us

Fig. 3 – The examined objects. – (Photos: Benedek Baranczó (Herman Ottó Museum), Nikolett Kovács; design: Béla Török).

	Ti	Fe	Ni	Cu	As	Ag	Sn	Sb	Pb	Bi
No. 14										
Surface of the object	0,12	0,18	0,51	74,45	2,97	1,43	13,87	4,84	1,38	
Surface of the sample	0,21	0,13	0,57	88,47	0,94	0,63	6,49	2,32	0,16	
No. 17										
Surface of the object	0,03	0,12	0,71	81,80	1,47	0,61	11,70	1,97	0,43	
Surface of the sample		0,06	0,64	90,82	0,53	0,29	6,43	1,08		
No. 15										
Surface of the object		0,25	0,74	81,79	1,05	0,36	13,49	1,58	0,67	
Surface of the sample		0,15	0,65	87,13	0,59	0,28	10,08	1,08		
No. 24										
Surface of the object		0,14	0,20	71,98	3,73	2,34	11,64	6,01	3,51	0,34
Surface of the sample		0,05	0,43	92,40	1,15	0,57	2,69	2,01	0,62	0,04
No. V26										
Surface of the object	0,20	0,35	2,11	48,09	1,56	0,36	46,00	1,06		
Surface of the sample		0,09	0,89	86,44	0,33	0,12	11,78	0,29		

Fig. 4 – Chemical compositions of the examined axes and sickle fragments (pXRF, wt%). – (Design: Béla Török).

about only the extent to which the contamination on the surface of the objects affects the measured results of the true chemical composition of the alloy. The results of the XRF analysis of axes and sickle fragments are reported in tabular form for each object in Figure 4. The data are expressed as wt%.

The samples were examined by optical and scanning electron microscopy (OM and SEM-EDS). For the examination, the samples were cut and embedded in epoxy-resin. The surface of the examined sections was mechanically polished and etched. A Zeiss Axio Imager M1m microscope was employed for optical imaging. The instrument is equipped with a computer-controlled stage, featuring composite imaging for the examination of the whole surface. The SEM-EDS examinations were performed with a Zeiss EVO MA10 electron microscope, equipped with an EDAX energy dispersive spectroscope.

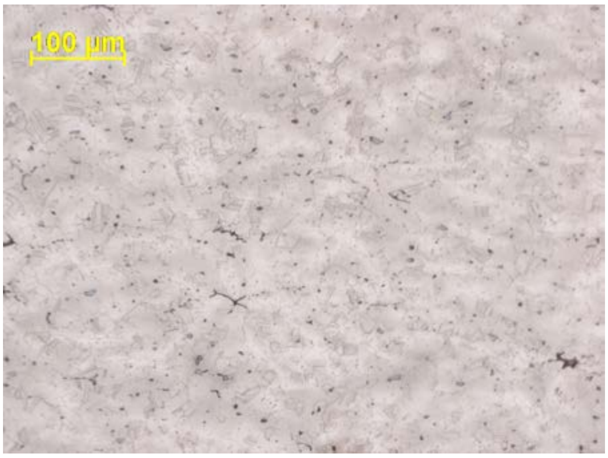

Fig. 5 – OM-image of the microstructure of the edge of socketed axe No. 14. – (Photo: Péter Barkóczy).

Socketed axes

Three samples were taken altogether from the two axes (Fig. 3). Microscopic examination showed that the hammered edge of axe No. 14. was recrystallized (Fig. 5), but this microstructure is not characteristic at the socket. The XRF results indicate that there is a high Sn and relatively high Pb enrichment at the surface, but in the inner part of the object, less As, Ag and Sb were detected as well. Based on the results, it can be stated that the object was cast and that the base material of the socket is tin-alloyed bronze with a relatively high level of antimony and slightly less but still significant arsenic (Fig. 4). However, the nickel content is notable here; this could originate from tetrahedrite ore with nickel content. At the edge of the axe, slight deformation in the grain structure was observed, which could be caused by usage.

In the case of the axe No. 17. no traces of usage were visible on the grain structure, but the axe was cast. The axe was made from a bronze alloy with a lower amount of Sb and Ni. The surface is heterogeneously enriched bronze with slightly lower Sn-content than before and very little lead contamination. The chemical composition of the examined sample showed less As and Sb, but here their amounts are almost the same (Fig. 4). Segregation on the observed section showed that the dendrites are outlined. The fine recrystallized grain structure showed that the edge of the axe was hammered and annealed. During the SEM-EDS examination, copper-sulphide inclusions, Cu-Sn intermetallic compound (beta) and lead segregations could be observed.

Sickle fragments

Four samples were cut from the three sickle fragments (Fig. 3). The composition of fragment No. 15 suggests that the object was made of high tin bronze and the tin on the surface was enriched only moderately. Lead is present in the alloy, but, only as an impurity. Sb and As are found in lower values than in the axes, but in similar proportions. Based on the SEM images, it can be stated that the sickle was hot-hammered after the casting process. However, the thicker part of the sample is not shaped, the copper-sulphide inclusions are flat and elongated at the edge, which was caused by hammering (Fig. 6A). In addition, lead inclusions can be seen in the microstructure. The angular phase observed in Figure 6B is the gamma-copper eutectoid, resulting from the decomposition of the beta intermetallic compound. This is a similar alloy to the No. 17 axe sample discussed above, but with a higher tin content. The high tin content means that the object is cast. A certain enrichment of tin and lead is also observed in this case, based on XRF measurements (Fig. 4). Due to centuries of corrosion, some elements like tin and lead might have redeposited on the surface, so the average values of these elements inside the alloy may be lower (Török and Giumlia-Mair 2022).

The fragment of sickle No. 24 (Fig. 3) was made of low tin bronze with significant arsenic and antimony content (Fig. 4). The object was cast and was not hammered afterwards (presumably because the sample was taken from the thicker side of the sickle) (Fig. 7A). The surface enrichment of tin is very high in terms of ratios. The chemical composition of the alloy as measured by XRF has about half as much arsenic as antimony on either the polished surface of the object or the sample, but more of both on the surface (Fig. 4). The surface of

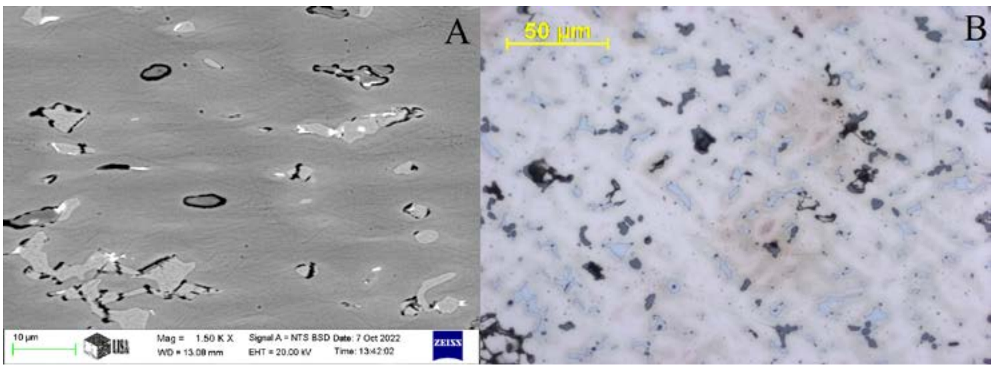

Fig. 6 – SEM- and OM-images of the sample of sickle fragment No. 15. – (Photo: Péter Barkóczy and Árpád Kovács).

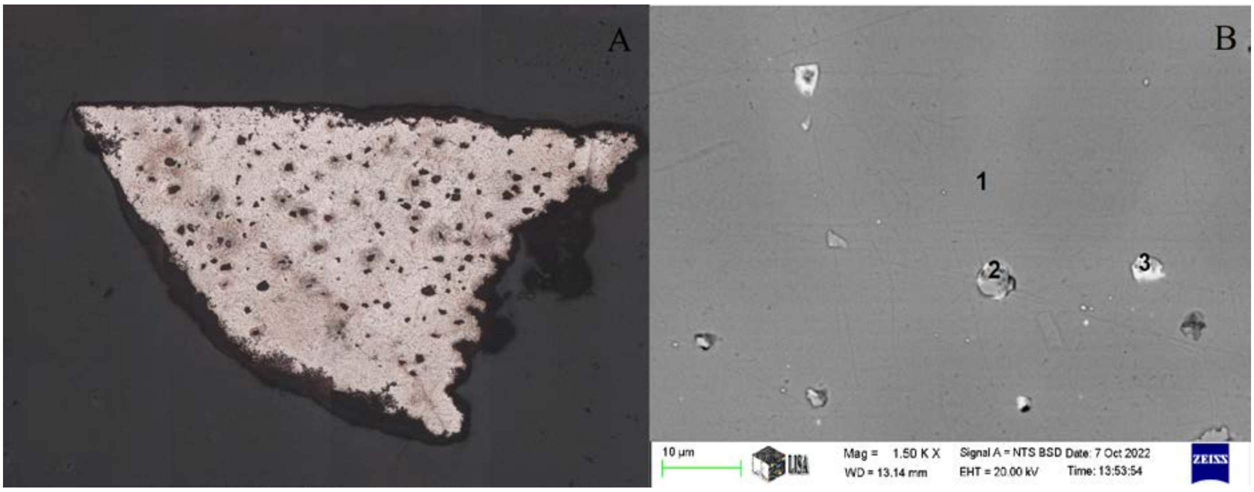

Fig. 7 – OM- and SEM-images of the sample of sickle fragment No. 24. – (Photos: Péter Barkóczy and Árpád Kovács).

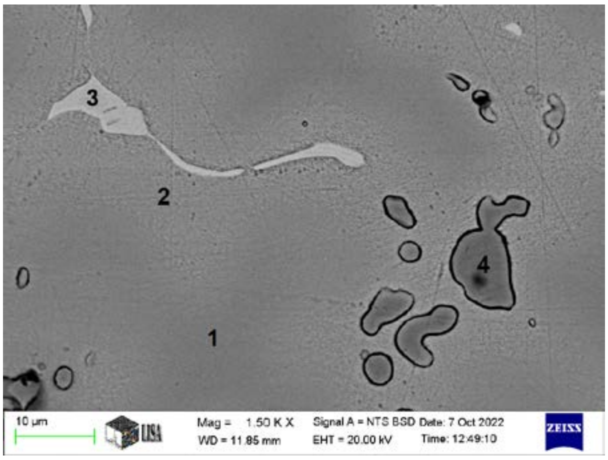

Fig. 8 – SEM-image of inclusions of the sample of sickle fragment No. V26. – (Photo: Árpád Kovács).

this sample had the highest silver content of all the samples tested. It is interesting to note that this sample was the only one with measurable levels of bismuth. The object is made of low tin bronze with significant arsenic and antimony content, but tin and lead, as a contaminant, were highly enriched on the surface. In the SEM image of Figure 7B, Point 2 is inclusion which is rich in antimony (Sb: 16wt%, As: 1wt%) and Point 3 is a lead inclusion. Based on the SEM-EDS investigation, the raw material of the sickle would be Freibergite $(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$), a composite sulphosalt mineral composed of silver, copper, iron, antimony and arsenic, a typical tetrahedrite type ore. It is supported by Inclusion 2 in Figure 7B.

The alloy of the sickle fragment V26 has a unique composition compared to the other objects examined. Almost as much tin as copper can be measured on the surface. On the polished surface of the sample, i.e., the inside of the object, there is a quarter of the tin, but still over 10wt%. However, no lead was measurable with either XRF or the EDS method. The antimony content is moderate compared to the other examined objects, but the nickel content is highest for this sample (Fig. 4). The SEM image in Figure 8 shows an interesting microstructure. The bright part marked by 3 is a copper-tin intermetallic compound (gamma, but also possibly delta). During crystallization, the tin is strongly enriched (13.92wt%) in the adjacent slightly brighter part (2), while the area marked by 1 contains less tin than average (4.10wt%). This indicates strong micro enrichment and rapid cooling.

Ingot and lumps

The examination of ingot 2022/8 and lump 2021/10/A (Fig. 3) showed interesting results. Ingot 2022/8 appears to be fresh raw material, even a primary metallurgical product. This is supported by the high arsenic and antimony concentrations and the fact that it contains technically no tin and lead (As = 4–4.5wt%, Sb = 4.5–5.4wt%, Ag = 1.3–1.9wt%, Sn, Pb and Ni < 0.1wt%, measured with portable XRF spectrometer). Its structure is coarse dendritic with a significant amount of pores (Fig. 9). In its microstructure, copper-antimony intermetallic phases (gamma and delta) were found. The tin content of the 2021/10/A lump is moderate (4wt%); however, it also contains significant amounts of antimony (4wt%), arsenic (2wt%) and silver (0.6wt%), and the nickel content is relatively high as well (0.7wt%). Nevertheless, the chemical composition and microstructure of the lump are well comparable to that of the ingot. The structure of the lump (Fig. 10) also contains copper-antimony intermetallic compounds – gamma (1) and delta (2) in Figure 10 – but is much more homogeneous than the ingot. In Figure 10, the white spots (3) are lead segregations. The role of lead is somewhat uncertain in the comparison of the ingot and the lump. While the ingot does not contain detectable lead, the XRF spectrometer has measured up

Fig. 9 – OM-image of the sample of ingot No. 2022/8. – (Photo: Péter Barkóczy).

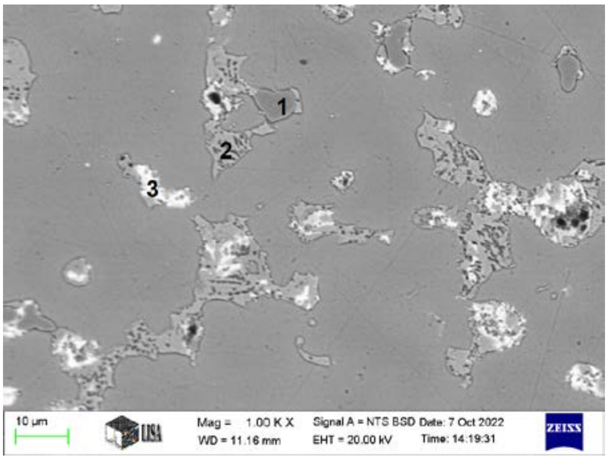

Fig. 10. – SEM-image of inclusions of the sample of lump No. 2021/10/A. – (Photo: Árpád Kovács).

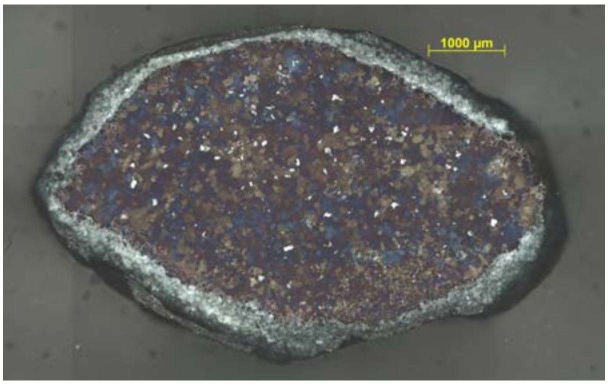

Fig. 11 – OM-image of the microstructure of the sample of lump No. 2021/10/D. – (Photo: Péter Barkóczy).

to 4wt% lead in some spots on the surface of the lump, presumably in an enriched state. One can conceive a technological sequence whereby the ingot, as raw material, was alloyed with tin, and during the alloying a lump, like sample 2021/10/A, could be formed as an intermediate by-product, while nickel could enter the alloy as an impurity, and cast to produce finished products such as the socketed axe No. 14. Lead may also be an impurity, usually found in segregates (Staniaszek and Northover 1983), but it may have been intentionally added to the alloy to make a more castable material.

The alloy of the lumps 2021/10/D and E is very similar to the alloy of the sickle V26. Both lumps were of course cast under fundamentally the same conditions, but the structure of sample 2021/10/D is slightly more homogeneous. The average chemical composition of the two lumps is almost identical, there is no measurable lead, but some lead and copper sulphide inclusions can be observed in the structure. In the case of the sample of the lump 2021/10/E, both a high tin phase (Sn: 89wt%) and a high copper phase (Cu: 99.5wt%) were found near the sulphide inclusions. The lump 2021/10/E is most likely left over from the alloying process, during alloying with tin. The lump 2021/10/D is a piece that has undergone homogenisation, perhaps it is a residue from the casting of a final product (Fig. 11). The sickle V26 could also have been made from this kind of material. Thus, theoretically, a lump 2021/10/E – lump 2021/10/D – sickle V26 technological sequence can be established.

Provisional conclusion and further aims of the research

The present paper aimed to introduce briefly an LBA metal hoard discovered recently in the territory of Northeast Hungary. The preliminary investigations tried to determine the hoard's character and outline the principles along which the research will continue. For a better understanding of LBA hoarding practices at the site of Vatta-Telekoldal-dűlő, the remains of Bronze Age settlement along the Csincse stream should be taken into consideration at a microregional level (e.g., Kalli 2017: 133–135; P. Fischl *et al.* 2020).

On a wider regional level, the presented finds should be compared to other hoards in the Carpathian Basin and especially in Northeast Hungary. Metal hoards have been relatively frequently deposited during the LBA in the area of Northeast Hungary, but their composition and character vary during the different periods (Hansen 1994; 2005; Kemenczei 1984; Mozsolics 1985; 2000). The presented assemblage corresponds to an often discussed depositional pattern described as 'scrap metal hoarding' (e.g., Dietrich *et al.* 2022; Hansen 1994: 360–363).

The initial archaeometallurgical analyses complement the preliminary macroscopic observations and highlight the possibilities of further interdisciplinary research, which will be able to answer questions related to classification based on chemical composition, production technique and raw material supply. Our research support the likelihood of local manufacture and local alloying for the above reasons. Further conclusions can be drawn from the preliminary examinations:

– The main manufacturing technique is casting; however, at the edge of the axes and a sickle, recrystallized (fully or partial) grain structure can be observed. This proves plastic deformation and annealing.
– The microstructure of numerous objects shows traces of microsegregation, which indicates rapid cooling.
– The main complements of the studied bronzes are arsenic, antimony, silver and tin. Nickel is also detected to a smaller or larger extent. Tin is added intentionally as an alloying agent.
– The high arsenic and antimony contents assume the tetrahedrite mineral group as the main raw material of smelting. The change in silver and nickel content indicates a different version of the ores of the tetrahedrite group. Tetrahedrite ores can be found in several places within a 50–70 km radius of the Vatta site.

These results will add valuable information to our present knowledge and will be comparable to the series of similar recent research (e.g., Gavranović and Mehofer 2016; Wrobel Nørgaard 2017; Mödlinger and Trebsche 2020).

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Deutschlandsberg-Hörbing and multi-period settlements at the edge of the eastern Alps – current research on the Bronze Age in western Styria

Florian Mauthner and Valentina Vidoz

Recent archaeological fieldwork in western Styria provided new insights into the Bronze and Iron Age as well as Roman period settlement in this area. Especially in Deutschlandsberg-Hörbing, remains of one of the largest Bronze Age settlements in the eastern Alps were researched in the last decades, where remarkable building structures and 'ritual' depositions were uncovered. Together with the results of other excavations in western Styria, we are now able to reconstruct a very dense settlement structure for the Bronze Age in western Styia as well as in Slovenia. Remains of Late Iron Age and especially Roman settlement activity was detected in the areas of earlier Bronze Age settlements. Based on the evidence from these multi-period settlements, it can now be assumed that they were of supra-regional importance for the south-eastern Alps, from the Bronze Age to the Roman period.

Keywords: settlements, settlement structures, buildings, Bronze Age, Iron Age, Roman period, southeastern Alps

Des travaux archéologiques récents sur le terrain dans l'ouest de la Styrie ont fourni de nouvelles informations sur l'âge du Bronze et du Fer ainsi que sur l'occupation de la période romaine dans cette région. Au cours des dernières décennies, en particulier à Deutschlandsberg-Hörbing, les vestiges de l'un des plus grands habitats de l'âge du Bronze des Alpes orientales ont été étudiés, où des structures de construction remarquables et des dépôts « rituels » ont été découverts. Grâce aux résultats d'autres fouilles réalisées dans l'ouest de la Styrie, nous sommes désormais en mesure de reconstruire une structure d'habitat occupation très dense de l'âge du Bronze dans l'ouest de la Styrie ainsi qu'en Slovénie. Des vestiges de la fin de l'âge du Fer et en particulier d'une occupation romaine ont été détectés dans les zones d'occupation antérieur de l'âge du Bronze. Sur la base des témoignages de ces habitats à plusieurs périodes, on peut désormais supposer qu'ils avaient une importance suprarégionale pour les Alpes du Sud-Est, de l'âge du Bronze à l'époque romaine.

Mots-clés : établissements humains, structures d'habitat, bâtiments, âge du Bronze, âge du Fer, période romaine, Alpes du Sud-Est

Batı Styria'daki son arkeolojik saha çalışmaları, bu bölgedeki Tunç ve Demir Çağı ile Roma dönemi yerleşimleri hakkında yeni bilgiler sağlamıştır. Özellikle Deutschlandsberg-Hörbing'de, Doğu Alpler'deki en büyük Tunç Çağı yerleşimlerinden birinin kalıntıları son on yıllarda araştırılmış ve burada dikkate değer bina yapıları ve 'ritüel' birikintileri ortaya çıkarılmıştır. Batı Styria'daki diğer kazıların sonuçlarıyla birlikte, artık Slovenya'da olduğu gibi Batı Styria'da da Tunç Çağı için çok yoğun bir yerleşim yapısını yeniden inşa edebiliyoruz. Erken Tunç Çağı yerleşimlerinin olduğu alanlarda Geç Demir Çağı kalıntıları ve özellikle Roma yerleşim faaliyetleri tespit edilmiştir. Bu çok dönemli yerleşimlerden elde edilen kanıtlara dayanarak, bunların Tunç Çağı'ndan Roma dönemine kadar Güneydoğu Alpler için bölgeler üstü bir öneme sahip olduğu varsayılabilir.

Anahtar Kelimeler: yerleşmeler, yerleşim yapıları, yapılar, Tunç Çağı, Demir Çağı, Roma dönemi, Güneydoğu Alpler

Introduction

Rescue excavations were undertaken in the area of Deutschlandsberg-Hörbing, a modern settlement in western Styria, in the south of Austria; here we present the latest results of the 2022 excavations in a wider context. On the one hand we will discuss the Bronze Age settlement with its surroundings and on the other hand later settlement periods in our research area, also including the results of research in the last decades in south-eastern Alps (Fig. 1).

Topography

Hörbing is part of Deutschlandsberg in western Styria in Austria. The eastern border of western Styria is the north-south flowing Mur river, and the western border is formed by the mountains of Koralpe and Gleinalm, which are also the border to Carinthia and Upper Styria. In the south of Styria are the mountains of Radlpass and Possruck constitute the boundary line to Slovenia. The region of hilly country around Deutschlandsberg extends from the foot of the Koralm, and the town itself is situated directly on the River Laßnitz.

During the Bronze Age the area was densely settled, which led to numerous reports of finds and excavations. The area of the Bronze Age settlements includes an area of 12,000m² along the River Laßnitz (Bernhard 2007: 205–206) (Fig. 2).

History of research

In the last few decades, a number of excavations were carried out in Deutschlandsberg, which indicate

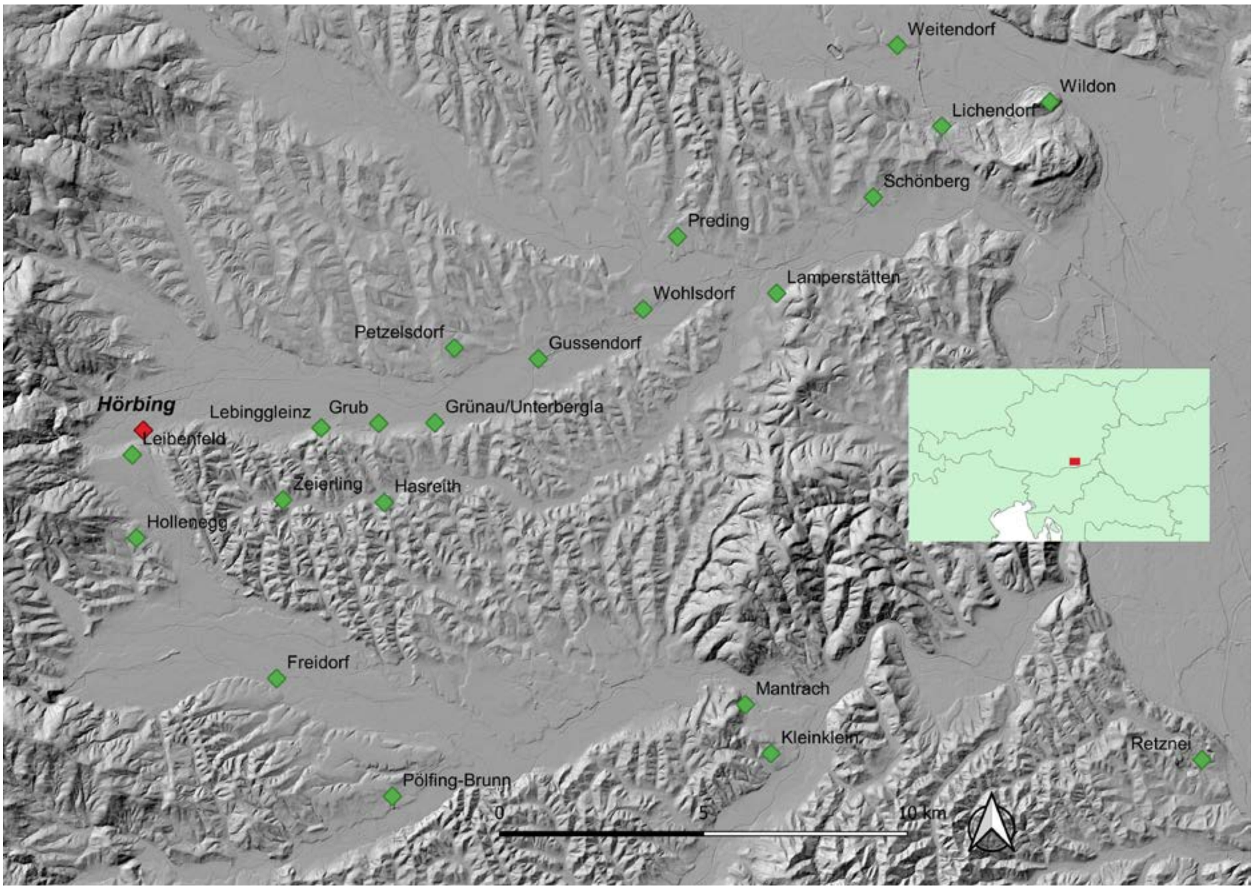

Fig. 1 – Bronze Age settlements in western Styria. – (Map: F. Mauthner).

Fig. 2 – Overview of modern Hörbing settlement. – (Photo: F. Mauthner).

extensive Bronze Age settlement. During the years 1990 and 1991, an large-scale emergency excavation under the management of Bernhard Hebert in cooperation with Burg Deutschlandsberg was conducted in Hörbing, during which many Bronze Age finds and structures came to light. The result of the excavation shows six houses from the Bronze Age, longhouses with mostly opposing wall posts and a constant width of three meters. The length of the houses varies between six and thirteen meters. A Bronze Age date for these houses, more specifically to the period from 1430 to 1310 cal BC, was established by radiocarbon dating (Hebert 1995:

Fig. 3 – Bronze Age buildings from 2022 excavation. – (Photo: F. Mauthner).

301; Bernhard 2007: 206). Based on the material found in this excavation, a two-phase occupation can be assumed (Bernhard 2007: 212). Following these results, archaeological investigations have been carried out on many new buildings in recent years, which has made it possible to better record the extent of the settlement, mainly by pits. The material found in these excavations also fits in well with the known findings (Fuchs 2015; Mauthner and Vidoz 2022).

The excavations in 2022

In this excavation, across almost the entire area of 12,000m^3 remains of the Bronze Age settlement were found. In addition to several storage pits and palaeochannels, some building remains were uncovered (Fig. 3). Building 1 is a two-bay post structure consisting of 16 post holes and a two-post porch. Inside the building of about 40m^3, no structures could be found except for a small ditch. One of the post holes shows the negative from a wooden post, which like the other post holes contained pottery fragments, charcoal remains and fragments of daub. The ground plan of Building 1 could be assigned to Type E of Bronze Age buildings according to Tiefengraber (Tiefengraber 2007: 93 fig. 13) and is, for example, comparable with Building V of the excavation Hörbing 1990 (Hebert 1995: 302) or with the buildings Grub 24 (Heymans and Szilasi 2022: 1143 fig. 4.106) and Grub 57 (Heymans and Szilasi 2022: 1184 fig. 4.147). A very remarkable aspect of Building 1 is the appendix built of two posts in the west.

Some metres north of Building 1, the remains of Building 2 were excavated. It has a rectangular shape with probably four posts on every side – in the southern part the post hole could not be detected – and a base area of approximately 16m^2. The related post holes were also filled with ceramics, charcoal, and loom weights. This building could be assigned to Type B according to Tiefengraber (Tiefengraber 2007: 93 fig. 13) and is comparable with Hörbing Building 4 (Hebert 1995: 302) or Building 5 of Sodolek in Slovenia (see Kavur 2007: 55 fig. 2). Also, some buildings excavated in Grub (e.g., Building 8, 21, 26, 49; Heymans and Szilasi 2022: 1126–1176) are comparable.

A remarkable layer was found in House III/2022, it shows a rectangular stone layer with rounded corners and three post pits in the west. Whether this paving was situated inside the building or indicated an

Fig. 4 – So-called 'house burial'. – (Photo: F. Mauthner).

external work area cannot be said with certainty at this time. Unfortunately, due to the intensive agricultural use of the site, no further interior structure inside the buildings has been discernible so far.

The so-called 'house burial'

One of the more interesting features is a pit that had been covered with larger stones (Fig. 4). After removing the stones, including some broken querns, the following picture appeared: A large number of pottery vessel fragments, most of which show traces of secondary burning, were placed in the pit, mixed with fragments of querns and loom weights as well as a wooden object. The majority of the pottery fragments could subsequently be restored, which is also why the shape of nine vessels could be completely reconstructed, which allows a dating to the transition from the Middle to the Late Bronze Age. The vessels show the typical range of forms of the Middle and Late Bronze Age, such as the vessel with lugs (Fig. 5.1) or the biconical vessel (Fig. 5.2). A cup (Fig. 5.4) and barrel-shaped vessels (Figs 5.3,5–6), one with decoration, and bowls (Figs 5.7, 6.4,6) complete the picture, together with other fragments.

There are several possible interpretations of the pit: An interpretation as a 'house burial' would be obvious, on the one hand because of the composition of the finds, with fine and coarse pottery as well as loom weights and querns, which depict a household. On the other hand, the objects in part show evidence of secondary burning and were probably intentionally destroyed. The reason for this would have been that when the settlement was abandoned, the contents of the house were ritually

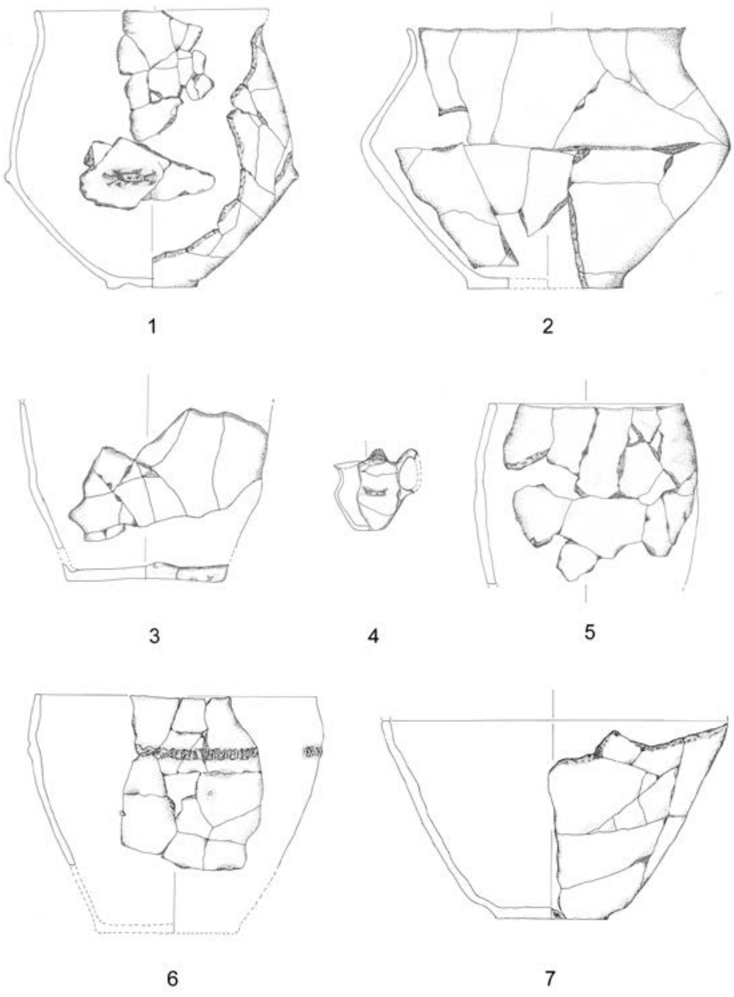

Fig. 5 – Pottery vessels and fragments form 'house burial'. – (Drawing: V. Vidoz).

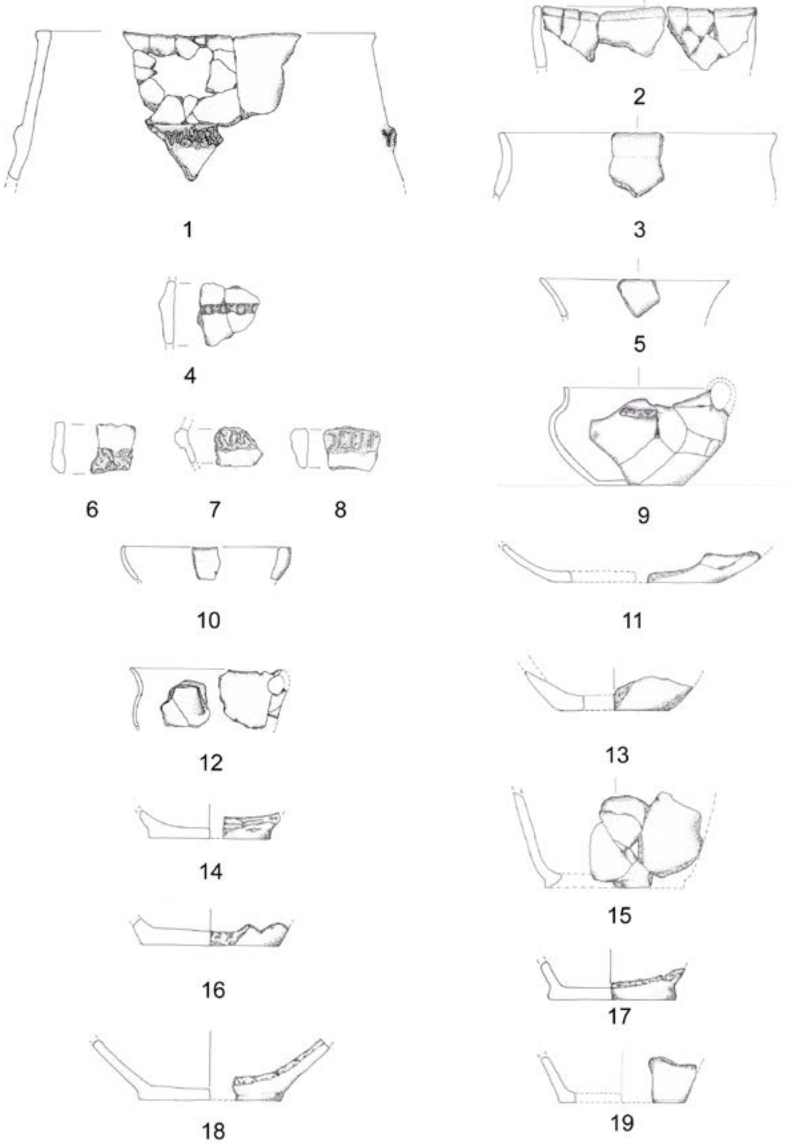

Fig. 6 – Pottery vessels and fragments form 'house burial'. – (Drawing: V. Vidoz).

burned near the site and then buried in the pit. The pit could also simply be a refuse pit, as the pottery, as mentioned above, was very fragmented. However, the question now arises as to whether the pit may have had another primary use, such as a possible storage pit. This must remain open for the time being, as no soil samples have yet been tested (Fig. 6).

Furthermore, there are other examples of such pits in western Styria, which are classified as refuse pits, pottery deposits or similar. A good comparison is the Bronze Age settlement of Schönberg, which was archaeologically investigated during the construction of the Koralm railway and where further pits were uncovered, which can be classified similarly to the 'ritual' pit at Deutschlandsberg Hörbing. The two pits designated as Object 609 have a similar infill. Both show a light grey/light grey-brown silt with iron oxide as well as charcoal and stone inclusions. The pottery found in them is also dated to the Late Bronze Age Transitional Urnfield Culture, as at Hörbing (ARGIS and Heymans 2014: 205).

Object 1213 also shows similarities. Again, this pit was filled with light grey silt containing iron oxide and charcoal. The only difference to the aforementioned pits is the presence of burnt bones, although it should be noted that the burnt bones weigh less than 1g and it is quite possible that they entered the pit through an animal burrow or similar disturbance. Furthermore, the pit contained a variety of pottery, which shows similarities to the pottery from Hörbing and is dated to the Middle Bronze Age (ARGIS and Heymans 2014: 324–325).

At Grub, located about 2.5km from Schönberg, a large number of such pits have been discovered, which are treated as refuse pits or pottery deposits. Most of the pits have a typical long oval shape, known from the Middle and Late Bronze Age, and often were put to secondary use, such as clay pits that were later used as refuse pits (Heymans and Szilasi 2022a: 1080–1081).

Not only the pits from Grub are similar in shape, they also contain pottery fragments. The fragments varied in size from pit to pit, and there were also charcoal and ceramic inclusions in the pits. The charcoal helped to date the pits, and radiocarbon dating places the pits in the Middle to Late Bronze Age.

The pit Object 1330 is the most similar in shape to the Hörbing pit. The steeply sloping wall shows no fire discolouration, only at the bottom of the pit were charcoal remains preserved. The large quantity of pottery was also exposed to secondary burning. It should be noted, however, that whole vessels were also deposited in the pit. Heymans refers to Object 1330 as a refuse pit. The pottery was probably secondarily burnt in a house fire and then thrown into the pit. It is possible that it was in fact a refuse pit, or that it may have been a ritual pit, since complete vessels have been preserved. The charcoal remains from the pit allow a dating to the Bz C2/D period (Heymans and Szilasi 2022a: 1067–1068).

Object 1374 likewise shows similarities to the Hörbing pit. It contained a variety of pottery as well as daub. In the case of the Hörbing pit, the pottery indicates that the pit was not only used in one period, but that it lasted from Bz B2 to Bz D. Even the pit from Hörbing shows use from the Early Middle Bronze Age to the Late Bronze Age. Object 1374 is again mentioned as a refuse pit, but more clearly as a deposit of household items (Heymans and Szilasi 2022a: 1069).

Finds

The pottery fragments found in the excavations in Deutschlandsberg-Hörbing show typical forms of the time, like mugs and jugs with handles or barrel-shaped pots. Also pots and biconical vessels, partially with stand-rings, were found. Especially the fine pottery shows a careful surface treatment with polished surfaces.

The ornaments and decorations used to decorate the vessels are particularly striking. They include incised ornaments such as hanging triangles, which usually have an oblique stroke, as well as so-called hourglass patterns. The motif of hanging triangles finds comparisons in western Styria, for example in Zeierling (Heymans 2022: 593–594 fig. 328), Grub (ornament type RO 4, cf. Heymans and Szilasi 2022b: 1249 fig. 5.12, RO 4) or Kainach near Wildon (Gutjahr 2011: 191 pl. 4,17; 196 pl. 9,43–47), but also in Slovenia, for example in Oloris (Type O 12; Dular *et al.* 2002: 158–159 fig. 111,O12). Hourglass patterns are also known in Grub (Ornament type RO 12; Heymans and Szilasi 2022: 1250 fig. 5.12,RO 4). One pottery fragment has curved incised decoration, which may have formed hanging triangles, as we know them from Kainach (Gutjahr 2011: 156, 196 pl. 9, 43–44) and also Oloris (Dular *et al.* 2002: pl. 8,1–2) (Fig. 7).

The also occurring 'metope friezes' consist of alternately arranged rectangles, which are filled with strokes; these 'friezes' usually appear together with hanging triangles. In addition, stamped ornaments also appear, which consist of carefully and closely arranged triangles. These multi-line stamp decorations are mainly known in areas north of the Alps, such as Bavaria or Salzburg (see also Bernhard 2007: 207–209).

In addition, a large number of vessel fragments with applied decoration are known. On the one hand, some of these come from the whole area with Bronze Age structures, mainly from the area of the stone foundation, but on the other hand, the larger quantity comes from the pottery deposit. These ornaments are made up of smoothly applied clay mouldings with a rounded cross-section, as they are also known from the Grub (Type AO 10; Heymans and Szilasi 2022b: 1247) or Oloris pottery (Type O1, Dular *et al.*: 155, 158 fig. 111,O1). In addition, there are a variety of finger dab strips in different designs, comparable to Grub (Type AO 3, Heymans and Szilasi 2022b: 1246) or Oloris (Dular *et al.* 2002: 155, 158 fig. 111,O3).

Evidence for Bronze Age craftsmanship

Throughout the excavation area, fragments and whole pieces of loom weights were found in the Bronze Age structures, with a high number coming from a post pit at Building 2, as well as from the pit with the pottery deposit, which indicates textile production. The loom weights found show the typical shape of Bronze Age loom weights, which are shaped like a truncated pyramid. Comparable findings are known from Grub (Heymans and Szilasi 2022: 1240–1241 fig. 5.11) and Oloris (Dular *et al.* 2002: pl. 65,2–5).

Also noteworthy is the star-shaped mark on one of the loom weights, which has so far been found mainly on Iron Age objects. These signs (dots, dashes, crosses, etc.) can also be found, for example, on the loom weights from Burgstallkogel near Kleinklein. The reason for these marks is not clear; maybe they were marks of the manufacturer of the weights or of the users/weavers. They also may have been important markers for the weaving process (Grömer *et al.* 2016: 111). In addition to textile production, a casting mould for ball-headed pins provides an important clue for the manufacturing of bronze objects (Tiefengraber 2007: 77)

Fig. 7 – Selected Bronze Age finds from excavations 2022. – (Photo: F. Mauthner).

Later settlement phases

The ridge of the Ulrichsberg together with the Kogelbauerkogel forms the southern end of the Deutschlandsberg basin. During a rescue excavation in 2020, traces of a Bronze Age settlement were uncovered, consisting of a pit house with a fireplace and an associated ditch-wall construction. A comparable situation is known form the Hallstatt period at the Heuneburg in Germany (Bofinger and Krausse 2005: 5 fig. 3). In the middle of the pit house, a fragmented pot with outwards finger-dabbing strip, flat shoulder with circumferential rib ornament and grip was found, which could be dated to Bz D/ Ha A1 (Mauthner 2020: D7954–D7957).

It may be possible to envisage a retreat to hilltop settlements for different reasons, such as the arrival of new population groups and associated looting and destruction by fire. For example, the Ulrichsberg hilltop settlement could be seen as the successor to the large, well-known Bronze Age settlement in Hörbing, especially in the 13th–12th centuries BC (Hebert 1995). In the 13th century BC, an abandonment of the settlement in Hörbing can be assumed, as the finds end with the Ha A1 level (Bernhard 2007: 212), while in this period the Ulrichsberg hilltop settlement is fortified. This phenomenon of Urnfield hilltop settlements also occurs in other south-west Styrian sites, as shown by examples on the Burgstallkogel near Kleinklein or on the Hoarachkogel/Bubenberg near Spielfeld.

Another interesting aspect of settlement history is shown by finds and features from the Late La Tène period as well as the Roman period, where particularly the early Roman finds deserve to be mentioned. A ditch-like feature with a stone-built structure in it and some post holes, which were also filled with spindle whorls, can be placed in the late La Tène period. The finds of the La Tène period consist exclusively of pottery fragments, mainly graphite pottery vessels and bowls, which can be considered Late La Tène based on their design. Comparable pottery is known from the La Tène settlement of Freidorf an der Laßnitz (cf. Praher 2015: 163 GT 3c). In addition, there are some spindle whorls, which also indicate textile production, comparable to finds from the Freidorf settlement (cf. Praher 2015: 150).

Finds and structures from the Roman period, which are probably associated with a *vicus* settlement, were to be expected during the excavations, due to findings from past excavations and the nearby Leibenfeld cemetery (cf. Haspl 2019). Two Roman period structures were uncovered, one of which was a filled-in ditch. Similar ditches are already known from earlier excavations and may have served for drainage or as boundary ditches for parcelling (Haspl 2019: 5–6, 51). The second layer

was a 4.8 × 5m pit filled with large river pebbles, which also contains early Roman pottery, but the structure cannot yet be convincingly interpreted.

The spectrum of finds comprises a heterogeneous selection of pottery fragments consisting of storage vessels and beakers, some of which are decorated with comb lines, similar to those known from the settlement at Deutschlandsberg (Haspl 2019: 126 pl. 2,5–6). Among the more remarkable finds are the fragments of a tripod bowl, which has parallels in the nearby graveyards of Leibenfeld (cf. Tiefengraber 2018: 767, 770) and Rassach (Fuchs and Hinker 2003: 139) and can be dated to the early Roman period.

The Late La Tène and Roman finds and features uncovered here fit well into the known picture of an extensive, *vicus*-like settlement of Hörbing, which in addition to residential buildings indicated by the position of post holes also shows craft activity areas with evidence for metalworking and pottery production (Haspl 2019: 106–110).

Discussion

Bronze Age settlements in western Styria

In the following, some sites from the near vicinity will be mentioned, to be able to give a short overview of the Bronze Age settlement of western Styria. As already indicated further above, western Styria is characterized by many west-east running river valleys, in which the settlement sites were established. Due to large infrastructure projects in recent decades, a large number of settlement sites could be recorded in the Laßnitz and Gleinz valleys.

Starting with the Laßnitz valley, in the area of Wohlsdorf near Wettmanstätten a Middle to Late Bronze Age settlement was explored in the years 2006, 2008 and 2009. It produced around 20 building plans and a cluster of post pits, which suggests a multi-phase development. Also discovered were two Middle Bronze Age wells. One of the wells accessed a local acquifer and has at least two construction phases. The bottom section of the well is well preserved and consists of carefully prepared timbers. The outside of the well is propped by sandstone boulders. The bottom of the well produced a Middle Bronze Age bowl (Fuchs 2011: 126–132).

In Grub, an area of 16,200m^2 was uncovered, which probably corresponds to a complete Middle Bronze Age settlement, with around 30 buildings, which indicates a village-like structure (Fuchs 2011: 134–136). The settlement of Grub has three phases, beginning with Phase 1 in the Middle Bronze Age. In this phase the arrangement of the longhouses with facing gable ends probably suggests prior planning. In the northeast of the settlement a craftsmen's quarter has been identified. At the transition from the Middle to the Late Bronze Age (Phase 2) we observe a change from a planned nucleated settlement to a more dispersed settlement with individual groups of buildings. In Late Bronze Age Phase 3 the cohesive settlement structure seems to have disintegrated, and sporadic settlement activity occurs, which continues into Ha A (Heymans and Szilasi 2022a: 1090–1094).

Hasreith is situated in the Gleinz valley and also forms part of Deutschlandsberg. It is located in the southeast of the municipality. In the years 1987 and 2001 two excavations took place. The first one as a rescue excavation and the second one as a planned research excavation. During the excavations, two periods could be identified, on the one hand structures dating to the Late La Téne period and on the other hand Bronze Age structures that were found on the eastern side of the slope.

To the first period belongs a pit measuring 4 × 2m, with two post holes. The pit was used for the extraction of bog iron ore. The second period features a big post-stand structure measuring 13 × 9m. It was used for iron processing, which is attested by iron blooms, furnace slag and by a roasting bed for roasting ore.

Freidorf in the Sulm valley is an interesting site, where the first excavation in 1979 was also a rescue excavation, under the Management of the ArchaeoNorico Burgmuseum. They discovered a pit with a depth of 0.5m. It had a dense infill, and the bottom is covered with burned bones. It is uncertain if they are human or animal. The second pit, excavated in 1999 has a depth of 0.4m, a length of 1.5m and the width varies between 0.8 and 1m. The finds from both pits include vessels with handles, bowls, foot vessels, conical-necked vessels and pots.

The new results from the Bronze Age settlement in Hörbing fit well with the copious evidence from Bronze Age settlements in the Laßnitz valley further to the east, where settlements are situated very close together, sometimes at less than one kilometre, and show a density of Bronze Age settlement sites so far not envisaged for the eastern Alps. We can recognize very large settlements, as for example in Grub, with over 30 buildings, attested through post pits, and settlements with well systems, which give us an insight into the water supply, as for example in Wohlsdorf. These settlements can all be dated between the 15th and 12th century BC (Fuchs *et al.* 2015: 332–334).

Topographically, the settlements are mainly located on the edge of the valley or on a slight slope, but always near or directly on a watercourse. A good example of a settlement with a direct location on a river course

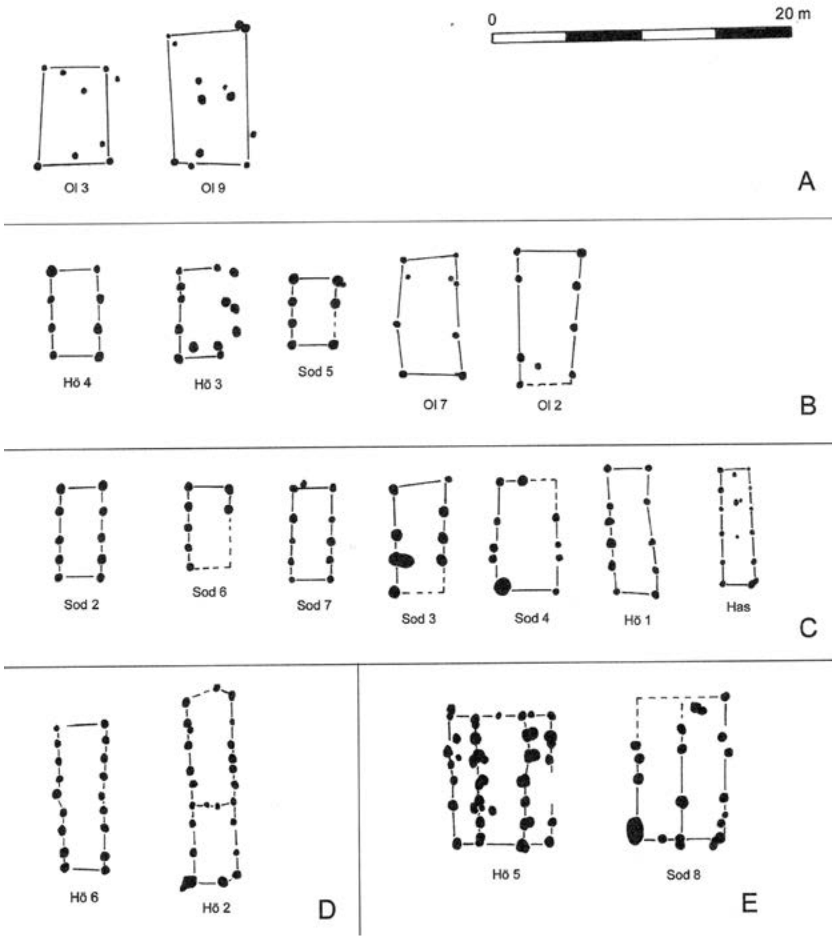

Fig. 8 – Typology of Bronze Age houses in the southeastern Alps. – (after Tiefengraber 2007, fig. 13).

is Hörbing, where the buildings are located on both sides of the river (Tiefengraber 2007: 91–92) and on river terraces.

Bronze Age comparisons from Slovenia

Also in Slovenia, the level of knowledge of the Bronze Age has increased due to large construction projects in recent decades. Due to the abundance of newly excavated settlement sites, only two important sites, Sodolek and Oloris, are highlighted here. The settlement at Oloris shows thirteen post buildings, which can be dated to Bz C2 and Bz D, based on the pottery. Furthermore, by comparing vessel types and ornaments, good comparisons and analogies can be drawn with the settlements of western Styria, especially Hörbing and Retznei (Dular 2011: 122–123). Another interesting settlement with eight buildings has been researched in Sodolek and shows continuity from the Middle Bronze Age to the Urnfield culture. The houses at this site measure 5–8m in length and 2.5–3.5m wide (Kavur 2007: 54–55).

Based on the settlements of Hörbing, Sodolek and Oloris, G. Tiefengraber tried to establish a typology for the buildings in the eastern Alps which comprises five types (Tiefengraber 2007: 92–95). The investigation of the extensive settlement at Grub has further refined the ground-plan-based typology of Bronze Age buildings in western Styria. We can now define Types A to K (Heymans and Szilaisi 2022a: 1044–1051). In addition to the pottery analogies mentioned above, also the ground plans of the buildings show clear similarities between the Middle Bronze Age in western Styria and northern Slovenia (Fig. 8).

Multiperiodic settlements in Western Styria

As the excavations in Deutschlandsberg-Hörbing have shown, there are also Late La Tène and Roman settlement remains known from Bronze Age settlement sites. Looking at western Styria from this point of view, several sites could be identified where settlements of the Late La Tène and Roman periods occupied the same location as previous Bronze Age settlements. In the following, a brief overview of a selection of sites will be presented and discussed against this background (Figs 9, 10).

Schönberg

Schönberg is part of to the municipality of Hengsberg and is located to the southeast of Deutschlandsberg. During the years 2006 and 2007 the commercial archaeological company ARGIS explored the area

Fig. 9 – Selected Late Iron Age finds from excavations 2022. – (Photo: F. Mauthner).

Fig. 10 – Selected Roman finds from excavations 2022. – (Photo: F. Mauthner).

affected by the Koralm railway project. The finds range from the |Middle and Late Bronze Age through the Urnfield culture and the Roman period to the early Middle Ages. The latest results show a dense settlement during the Bronze Age and the Roman period. Bronze Age features are concentrated mainly in the southwest of the excavated area and the Roman remains are mostly located at the western border on Plot 299.

The Bronze Age evidence consists mainly of Middle and Late Bronze Age settlement remains with numerous post pits which can be related to building plans. The pits also produced finds of cups and other small vessels. The Roman occupation dates to between the 1st and 2nd centuries AD and consists mainly of wooden buildings. This was first demonstrated in Hengsberg. Other pit features can be interpreted as drainage ditches (Oberhofer 2015: 11–12).

Södingberg

In the vicinity of Södingberg, another multi-period settlement area was investigated during the excavation of a Roman villa and an associated geophysical survey. The first settlement remains date back to the Bronze Age and consist of post holes and pits. The ground plans of some of the buildings, recognizable from the post holes, are overlapping, so that two Bronze Age building phases can be inferred. Based on the finds, the two settlement phases can be dated to Bz C2 and Bz D.

La Tène period settlement activity at the site was already known from stray finds. The excavation revealed mainly post pits and isolated refuse pits, as well as the fact that the La Tène period settlement was enclosed by two concentric ditches. Whether the ditches were already part of the settlement from the beginning or whether the settlement was only later enclosed by ditches – and probably also ramparts with palisades – cannot be determined. In any case, Södingberg can be interpreted as a fortified lowland settlement (in French: *habitat enclos*), which begins in LT C(2?) and exists until the end of the end of LT D2. Finds from the early Roman period are definitely lacking, so a continuity from the La Tène settlement to the Roman villa can be ruled out, but there is still remarkable continuity at this site (Groh *et al.* 2008: 329–337).

The focus of the excavations at Södingberg was the exploration of the Roman manor house, which consists of three building structures and belongs to the type of square villa that is widespread in the south-eastern Alpine region. The construction of the villa can be dated to the early 2nd century AD; at least parts of the villa are intentionally abandoned towards the end of the 4th century AD. A chronological sequence of the two differently oriented structures in the north cannot be proven on the basis of the excavations; consequently, contemporaneity and a uniform building program could be suggested (Groh *et al.* 2008: 322–324, 328).

Conclusions

The recent excavations confirmed the picture of one of the largest Bronze Age settlements in the eastern Alps as situated in Deutschlandsberg Hörbing. The settlement has buildings in the form of post and beam structures, as known throughout the southeastern Alps, but now for the first stone pavements are attested for the Late Bronze Age. The high settlement density in western Styria could possibly be related to the presence of copper ore deposits in the Koralm area, as perhaps indicated by finds of casting moulds (Tiefengraber 2007: 76).

The area around Hörbing was also a popular settlement site in the Late Iron Age and in Roman times, as finds and excavated features demonstrate. Across western Styria, Bronze Age sites appear to have attracted also Late La Tène and Roman settlement, as can be shown by the examples of Södingberg, Retznei or also Schönberg. On the basis of these new results, supra-regional importance can probably be assumed for the entire south-eastern Alpine region, as can be shown by a high settlement density in the Bronze Age and the important central places of the Iron Age, such as the Burgstallkogel or the Postela.

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Typological examination of Middle and Final Bronze Age (1625–800 BC) pottery from the Eremita Cave in Borgosesia (Vercelli, Italy)

Lekë Shala, Eve Derenne and Marie Besse

The Eremita Cave is located in the northwest of Italy, in the province of Piedmont, in the Monte Fenera Massif. Ten years of excavations (2012–2021) conducted by the Laboratory of Prehistoric Archaeology and Anthropology of the University of Geneva, under the direction of one of us (MB), revealed that the cave was used for burials during the Middle and Final Bronze Age (1625–800 BC) and yielded pottery, fauna, bronze artefacts, lithic industry, and cremated human remains. The ceramic assemblage consists of 2982 sherds. The study of the pottery revealed the minimum number of vessels and their main morphological characteristics. Together with an overview of the stratigraphic and chronological sequences, the study provides further information on the function of the cave and the chrono-cultural context. Through comparisons with other sites, this study explores the movement of people, ideas and artefacts.

Keywords: Eremita Cave, Bronze Age, pottery typological examination, archaeometry

La Grotte de l'Eremita est située au nord-ouest de l'Italie, dans la province du Piémont, dans le massif du Monte Fenera. Dix années de fouilles (2012–2021) menées par le Laboratoire d'archéologie préhistorique et anthropologie de l'Université de Genève, sous la direction de l'une d'entre nous (MB), ont révélé que la grotte était utilisée pour des sépultures durant l'âge du Bronze moyen et final (1625–800 av. J.-C.) et a livré des poteries, de la faune, des objets en bronze, une industrie lithique et des restes humains incinérés. L'assemblage céramique se compose de 2982 tessons. L'étude de la poterie a révélé le nombre minimum de récipients et leurs principales caractéristiques morphologiques. Outre un aperçu des séquences stratigraphiques et chronologiques, des informations supplémentaires sont fournies sur la fonction de la grotte et le contexte chrono-culturel. À travers des comparaisons avec d'autres sites, cette étude explore le mouvement des personnes, des idées et des objets.

Mots-clés : Grotte de l'Eremita, âge du Bronze, étude typologique de la céramique, archéométrie

Eremita Mağarası, İtalya'nın kuzeybatısında, Piedmont ilinde, Monte Fenera masifinde yer almaktadır. Cenevre Üniversitesi Prehistorik Arkeoloji ve Antropoloji Laboratuvarı tarafından, içimizden birinin (MB) başkanlığında yürütülen on yıllık kazılar (2012-2021), mağaranın Orta ve Son Tunç Çağı'nda (MÖ 1625-800) mezarlar için kullanıldığını ve çanak çömlek, fauna, bronz eserler, taş endüstrisi ve yakılmış insan kalıntıları içerdiğini ortaya çıkarmıştır. Seramik topluluğu 2982 parçadan oluşmaktadır. Çanak çömleklerin incelenmesi, minimum kap sayısını ve bunların ana morfolojik özelliklerini göstermektedir. Stratigrafik ve kronolojik sıralamaya genel bir bakışla birlikte, mağaranın işlevi ve krono-kültürel bağlam hakkında daha fazla bilgi sağlanmıştır. Bu çalışma, diğer yerleşimlerle karşılaştırmalar yaparak insanların, fikirlerin ve eserlerin hareketini araştırmaktadır.

Anahtar Kelimeler: Eremita Mağarası, Tunç Çağı, çanak çömlek tipolojik inceleme, arkeometri

Introduction

This paper presents the results of the typological study of the pottery recovered from Eremita Cave, located in northern Italy, in the Piedmont region, in the territory of Borgosesia municipality. The site represents an important archaeological context for analysing the social and ideological development of the Middle and Final Bronze Age in the southern Alpine region of Central Europe. This work focuses on the typological features of the pottery collected from Eremita Cave.

Pottery is an integral part of everyday life, from the sacred to profane, regardless of status. As pottery often plays an important role in communication and religious life, it can also provide insights into deeper and less tangible aspects of past cultures, such as belief systems, ritual activities and identity (Quinn 2013; Skibo 2013: 1–25). As such, it is an important resource for interpreting the activities of past peoples and reconstructing aspects of their cultures. Pottery interpretation is therefore a method of attempting to answer research questions relating to the chrono-cultural context, economy, and use of the site.

The analytical process for this study unfolded in three steps: first, the archaeological and geological background of the cave were specified. Secondly, the minimum number of vessels was reconstructed on the basis of macroscopic and morphological observations.

Finally, these vessels were categorized typologically and chronologically, and were projected onto both the stratigraphy and the excavation plans. The analysis of morphological characteristics was an objective, using the orientation of the profile, the type of rim, and other morphological features related to the body shape as indications. Decorative categories were equally important and were distinguished by shape, technique, and position on the vessel. Typological comparisons were made with other sites, in the region and beyond. The results of this study provide important data that helps characterize the function of the cave and discern its significance in a wider cultural and environmental context.

Archaeological and Geological Background

Eremita Cave

The Eremita Cave (Fig. 1) is located in Piedmont, northern Italy, in the Monte Fenera massif, within the 'San Salvatore' dolomite. It opens on the western slope overlooking the Val Sesia at an altitude of 598m (Derenne *et al.* 2020). The massif lies at the entrance to several valleys, to the north leading to passes that give access to the Upper Rhone Valley in southwestern Switzerland, and to the south towards the Po Plain (Besse and Viola 2013a).

Monte Fenera

Monte Fenera, where the Eremita Cave is located, is the only massif composed of dolomites and limestones in this part of Val Sesia. It is located near two tectonic lines, the Cremosina and the Colma (Fantoni *et al.* 2005). The geological sequence of Monte Fenera consists of a basement of gneissic schists and Precambrian volcanic rocks. It is followed by a major Mesozoic sequence of about 300 meters of dolomite, about 10 meters of red sandstone, and about 250 meters of siliceous and marly limestone (Fantoni *et al.* 2005). The fossil remains of a super-volcano, active 290 million years ago, whose caldera reached a diameter of 13 km, are visible in the regional geology (Quick *et al.* 2003). During the last glacial maximum of the Pleistocene, Alpine glaciers reached Monte Fenera. Their retreat began around 21,000 BC, exposing the massif around 14,000 BC, which may have influenced the formation of cavities in its dolomite (Berruto 2011).

Monte Fenera encompasses about 70 caves. Some of them contain traces of human occupation dating to between the Middle Palaeolithic and the Late Middle Ages (Gambari 2005). Most of these caves were formed during the Messinian period (Bini and Zuccoli 2005), before being modified and enlarged during the climatic changes of the Pliocene to Pleistocene transition (Berruto 2011). Facing west, the view from the entrance of the Eremita Cave overlooks the valley where the Sesia River flows from its source in the Monte Rosa glacier around the low hills of Gattinara and Romagnano Sesia, eventually reaching the plain where it joins the Po at Casale Monferrato (Besse and Viola 2013a). The meandering course of the Sesia River crosses all three topographical areas. Such factors explain the development of important karst phenomena in the river.

Since the 18th century, a significant number of archaeological sites have been identified on Monte Fenera, although the bulk of the discoveries were made during the first half of the 20th century, under the impetus of Carlo Conti (1931). As discussed previously, several human occupations have been documented on

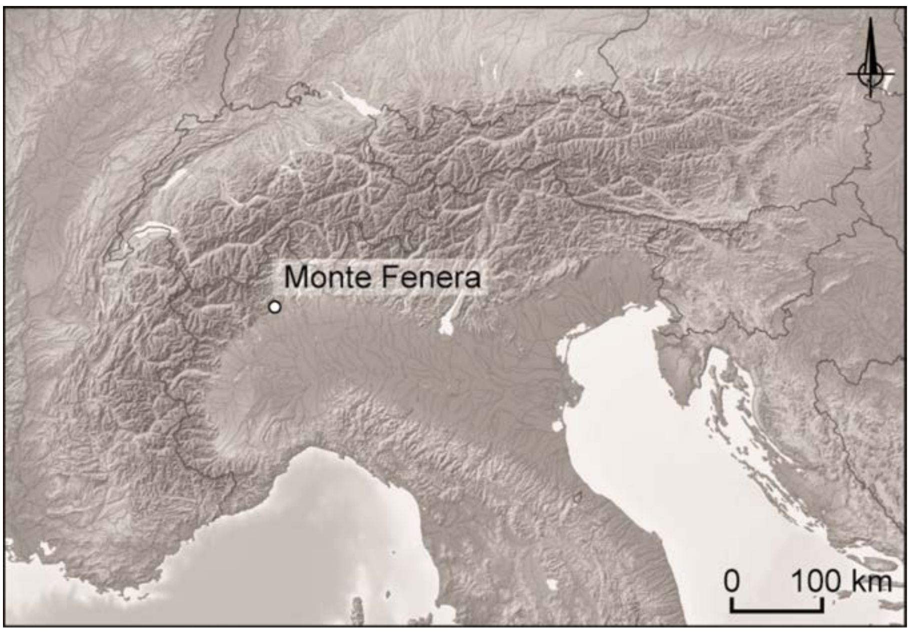

Fig. 1 – Location of Monte Fenera at the scale of the Alps. – (after Derenne et al. 2020: fig. 1).

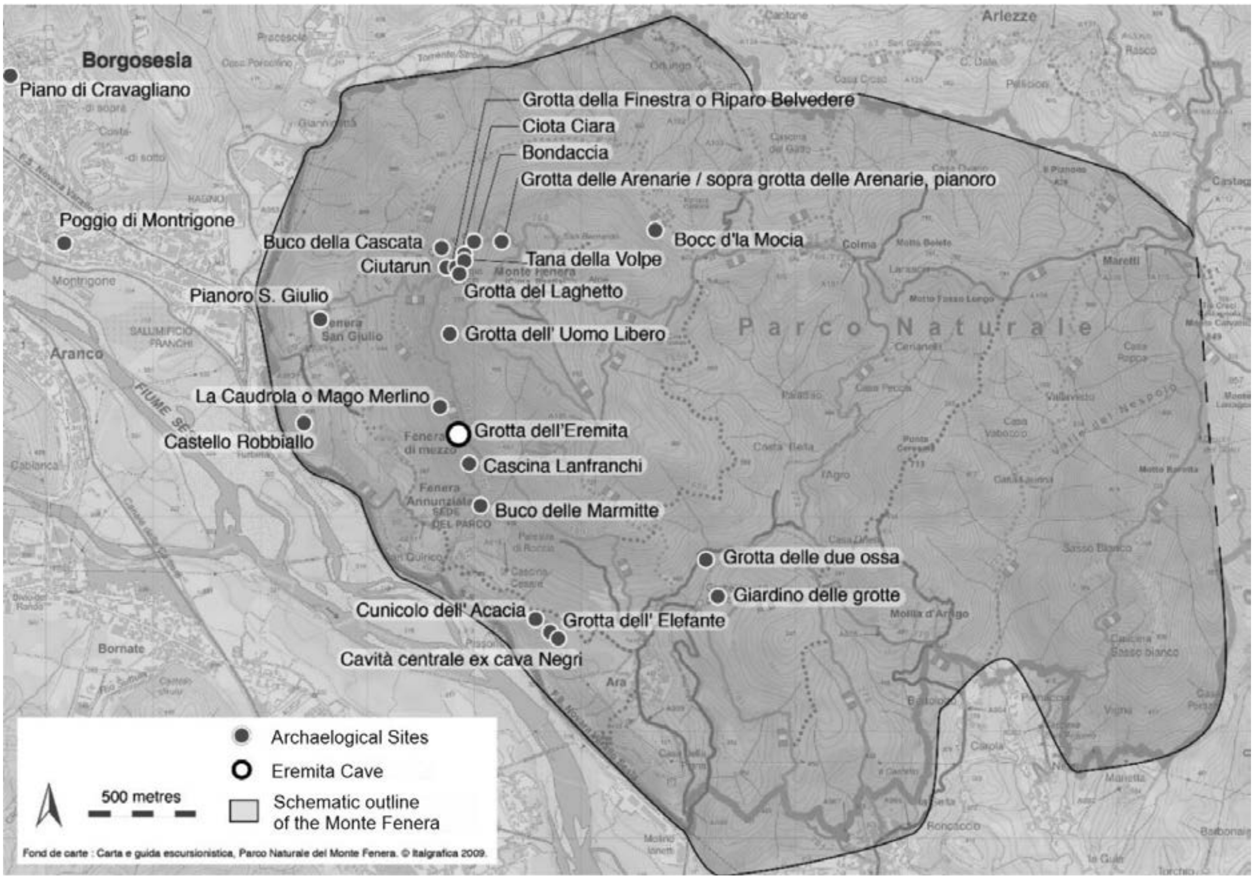

Fig. 2 – Distribution map of the main archaeological and palaeontological sites around and within Monte Fenera. – (after Besse and Viola 2013b, fig. 2).

Monte Fenera and in its immediate surroundings (Fig. 2). The most ancient one, the Ciota Ciara Cave (675m), is the only Middle Palaeolithic site known to date (Arnaud *et al.* 2021), excavated under the direction of Marta Arzarello of the University of Ferrara. Neolithic evidence comes from the terrace of Fenera S. Giulio (414m), and the cave of Riparo del Belvedere (662m). The Chalcolithic, meanwhile, is represented by the Uomo Libero Cave (620m), Ciotarun (635m), and the hill of Montrigone. The terrace of Castello di Robbiallo (354m) shows Chalcolithic and Early Bronze Age occupations, while the Tana del Volpe Cave (661m) yielded only Early Bronze Age material. Early and Middle Bronze Age remains have also been found in the Laghetto Cave (701m) (Besse and Viola 2013a; Derenne 2016).

Monte Fenera is rich in mineral resources, several of which are accessible and offer a variety of different types of raw materials (Berruto 2011). Flint is present in the form of spongolite, both on the summit and on the southern slopes; the limestone layers are accompanied by sandstone, the base of the massif contains quartz deposits, while the western slopes yield jasper. Quartz and jasper can be found along the various streams in the massif, as well as opal (Derenne 2016). Monte Fenera, with its numerous caves and resources, offers a strategic position which allows for temporary stops during north-south Alpine crossings.

2.3 History of research in the Eremita Cave

At the end of the 1980s, the *Gruppo archeo-speleologico di Borgosesia* (GASB) excavated two test trenches, which yielded archaeological material from different historical periods. A bone button, which is on public display at the Carlo Conti Museum in Borgosesia (Derenne 2016), was interpreted by the GASB as dating back to the Copper Age. This same button attracted the interest of the University of Geneva team and led to the organisation of a survey campaign (Besse and Viola 2013a; Besse and Viola 2013b). Thus, in 2012, the Laboratory of Prehistoric Archaeology and Anthropology at the University of Geneva began work in the Eremita Cave. The team, led by one of us (MB), uncovered ceramic and bone remains, as well as a metal pin and spiral beads, justifying a request to the Italian authorities for further excavations (Derenne 2016).

The excavations undertaken in the cave combined two essential approaches: stratigraphic and planimetric. The Eremita cave was investigated from an absolute depth of -185 (120cm below the surface) in 2013 to

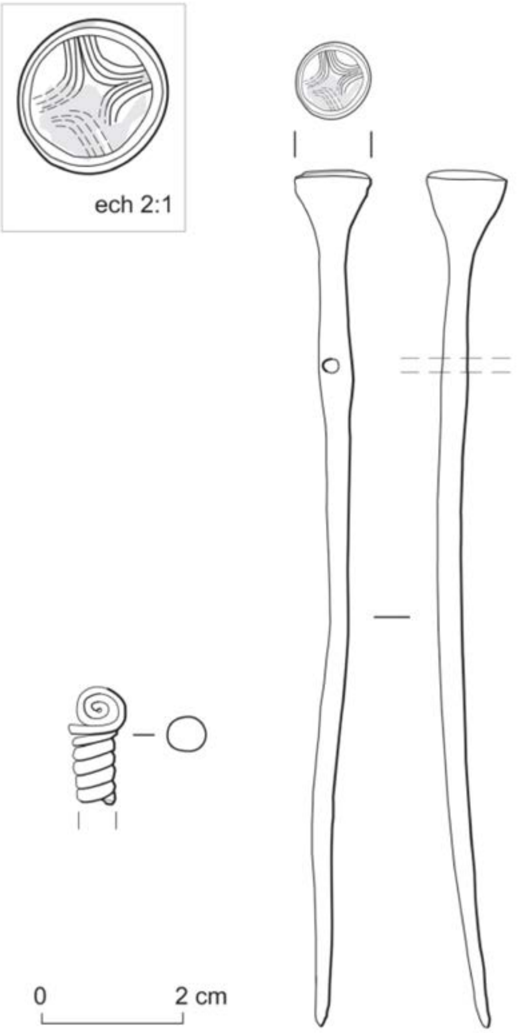

Fig. 3 – Bronze pin and spiralled ornament from the Eremita Cave. – (after Besse et al. 2014, fig. 6).

-306 (198.4cm below the surface) in 2021. A series of 2,982 pottery sherds, associated with fauna, cremated human remains, flint and bronze objects (Fig. 3) were discovered in the excavated layers. All finds were recorded according to their respective stratigraphic unit (hereafter US). The latter were determined from stratigraphic profile no. 1. To specify the absolute chronology of the site, sixteen radiocarbon measurements were made at the Swiss Federal Institute of Technology in Zürich.

Chronological sequences of the cave

Sixteen radiocarbon samples were selected and sent for dating by Dr. Irka Hajdas (Swiss Federal Institute of Technology Zürich) (Figs 4 and 5). Only thirteen of these are presented below, since three of them were not consistent with their stratigraphic position. Anthracological analyses were carried out by Janet Battentier (University of Geneva) on the second batch of samples, to select short-lived species whenever possible. The radiocarbon data obtained from these samples revealed that the cave was used for burial purposes during the Middle (1625–1325 BC) and Final Bronze Age (1250–800 BC) (Besse and Viola 2013a; Besse *et al.* 2014; Derenne *et al.* 2020; Rubat-Borel *et al.* 2022) (Fig. 6).

Two charcoal samples were selected because they belonged to US10, the black layer that sealed the stratigraphic sequence at about -130 cm. One sample each was taken from US16, US17, and US21, respectively; two from US14, and three from US18. Four samples were selected from US19, including two specifically for their relationship to the area where the bronze pin and beads were found. This layer was particularly

Sample code	US	Sample number	Dating BP	2 sigma (prob. 95.4%) (IntCal20)	Material	Selection of samples after anthrocological analysis (by J. Battentier)
BE15-F5-prCH4	10	ETH-64659	2794 ± 27 BP	1013–841 cal BC	charcoal	No
BE14-E4-prCH14	19	ETH-64658	3323 ± 28 BP	1681–1512 cal BC	charcoal	No
BE13-E2-prCH6	19	ETH-64656	3334 ± 28 BP	1729–1520 cal BC	charcoal	No
BE14-E4-prCH10	19	ETH-64657	3404 ± 28 BP	1864–1619 cal BC	charcoal	No
BE15-F5-prCH2	10	ETH-104336	2688 ± 22 BP	900–804 cal BC	charcoal	No
BE16-F3-prCH5	19	ETH-104337	3159 ± 22 BP	1499–1400 cal BC	charcoal	No
BE18-F3-prCH105	18	ETH-104338	3294 ± 25 BP	1617–1507 cal BC	charcoal	Yes
BE18-F3-prCH106	18	ETH-104339	3318 ± 24 BP	1663–1511 cal BC	charcoal	Yes
BE18-G5-prCH111	14	ETH-104340	3475 ± 22 BP	1881–1700 cal BC	charcoal	Yes
BE18-F4-prCH118	17	ETH-104341	3207 ± 24 BP	1509–1426 cal BC	charcoal	Yes
BE18-F5-prCH131	14	ETH-104342	3318 ± 22 BP	1628–1516 cal BC	charcoal	Yes
BE18-F5-prCH136	21	ETH-104343	3363 ± 25 BP	1740–1543 cal BC	charcoal	Yes
BE18-G3-prCH137	18	ETH-104344	3275 ± 25 BP	1615–1466 cal BC	charcoal	Yes

Fig. 4 – Radiocarbon measurements for the Middle and Final Bronze Age occupation of the Eremita Cave.

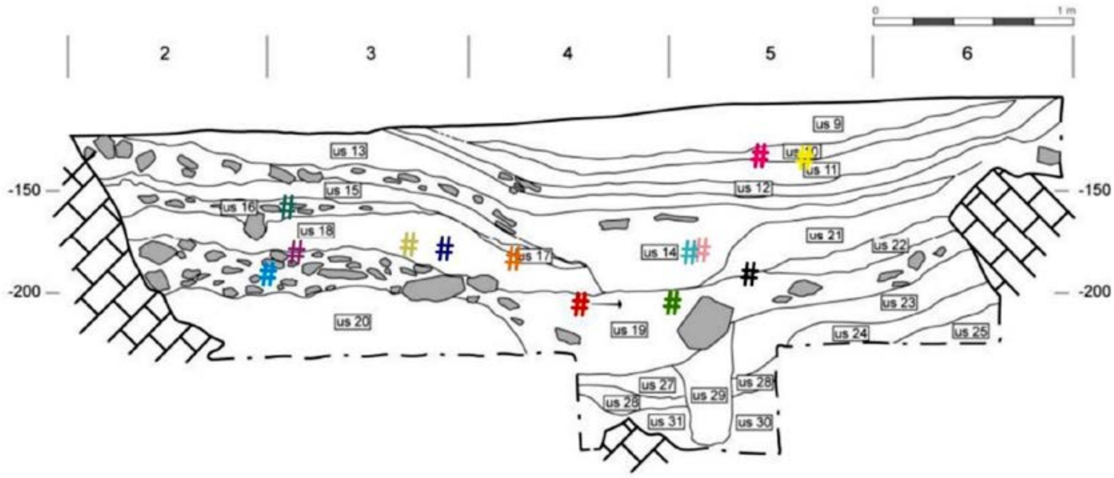

Fig. 5 – Projection of the 13 charcoal samples onto Stratigraphic profile no. 1.

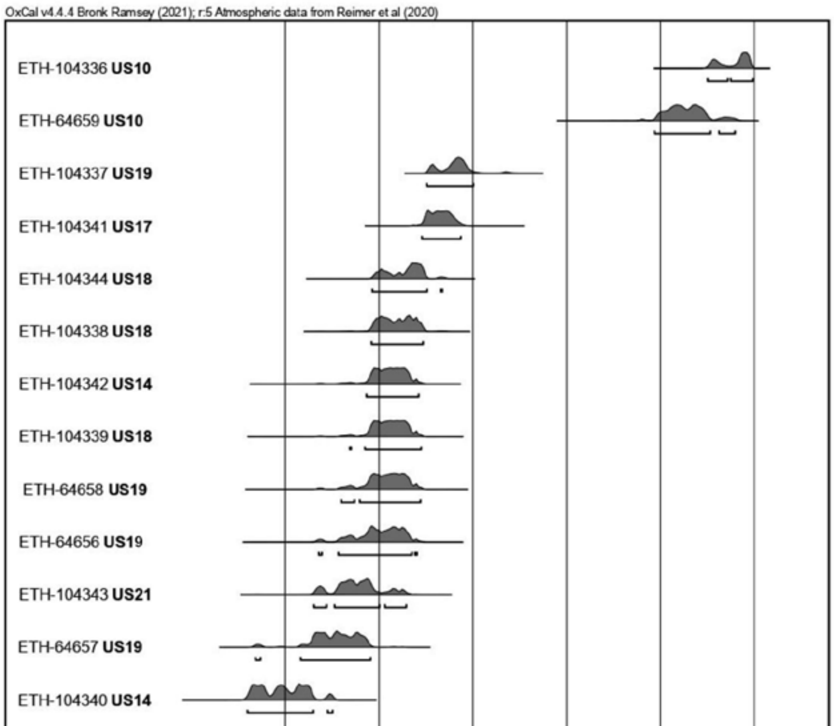

Fig. 6 – Calibration of the 13 radiocarbon dates from the Eremita Cave. – (Calibration with OxCal 4.4.4 [Bronk Ramsey 2021], based on the IntCal20 calibration curve [Reimer et al. 2020]).

important to date, as it yielded most of the pottery from the assemblage, together with a high concentration of lithics, faunal bone fragments, and cremated human remains. Apart from US10, which was dated to the end of the Final Bronze Age, all the samples date to the Middle Bronze Age.

Methods

A total of 2,982 pottery sherds weighing 35.5kg were recorded in a database. Each sherd was examined and documented recording two distinct types of information: (1) general details such as the inventory number, location, square metre, layer, spit, and chronology, (2) information on the pottery itself, i.e., typology (rim/base/handle/decoration), exact 3D position (x, y, z), length (in cm), width (in cm), thickness (in cm), weight (in grams), state of preservation, colour of the outer surface, colour of the inner surface and colour in cross-section.

Laboratory data collection

In order to determine the minimum number of vessels, general information on the macro-paste and typological information on the pottery was used. Diagnostic sherds

Fig. 7 – Vessel sherds, including a lug, photographed in situ during the 2021 excavation campaign.

(Fig. 7), such as rims, bases, handles, carinations and decorations, made up 13% of the corpus (n = 297) whereas the non-diagnostic pottery sherds — body fragments — represented 87% of it (n = 1997). Out of the 297 diagnostic sherds, 159 were rim fragments, 36 bases, 21 vertical or lug-shaped handles, 27 carinated sherds, and 54 sherds with decorations (cordon, fingerprints, incisions, etc.).

However, 2,124 sherds out of a total of 2,982, for a weight of about 6.4kg, were smaller than 1cm and could not provide sufficient macroscopic and typological data, due to their highly fragmented nature; they were therefore not taken into consideration for the rest of the study.

The remaining sherds (n = 858, *c.* 29.1kg in total weight) were selected for further study, and the minimum number of vessels was determined on the basis of this narrowed-down corpus. Once the corpus for further analysis had been selected, two main processes took place: (1) macro-paste grouping and (2) further sub-grouping based on morphological features.

First, the selected group — 858 pottery sherds — was analysed macroscopically, looking at attributes such as surface treatment, hardness, thickness, and colour in cross-section. The classification of the macro-pastes was defined solely from the characteristics of the inclusion. Following this analysis, the corpus was classified into ten paste groups. For each of them, a schematic diagram was created with the visible characteristics of the most representative sherd, such as colour and size of inclusions. In the classification, each group of recurrent paste characteristics was labelled macro-paste and numbered consecutively (e.g., MP. 1, MP. 2 … MP. 10). The characteristics defining each group (colour, size, and lustre of inclusions) were recorded in a table. In addition, a close-up photograph of the paste was taken.

In a second step, the typologically diagnostic fragments of each macro-paste group were determined. Of the total number of sherds selected (858 fragments), 289 (33%) were diagnostic sherds. The typological classification process was pursued within the ten macro-paste groups by classifying rims, handles, bases, and carinated sherds according to shape, size and decoration, bringing the number of sub-groups to 26, the minimal number of vessels (MNI).

The positional data (x, y, z) of the sherds — in association with the specific vessels they belonged to — were then processed with the ArcGIS software. This provided their exact location in three dimensions and allowed us to project them onto both the stratigraphic profile (Fig. 8) and the excavation plans (Fig. 9). The layers correlated with changes in typology, manufacturing techniques and depositional processes. This spatial analysis also revealed the differences in the weight distribution of the fragments on the excavation plan.

Results

Vessels and categories

Based on the selection criteria and sub-groups identified through the petrographic and morphological analysis, a minimum of 26 vessels (MNI) have been identified. Out of the 26 vessels, the rounded-lip type is the most common, with a total of 13, followed by five vessels with a bevelled inner rim. Four vessels have flattened rims and one has a thinned rim. For three vessels, the

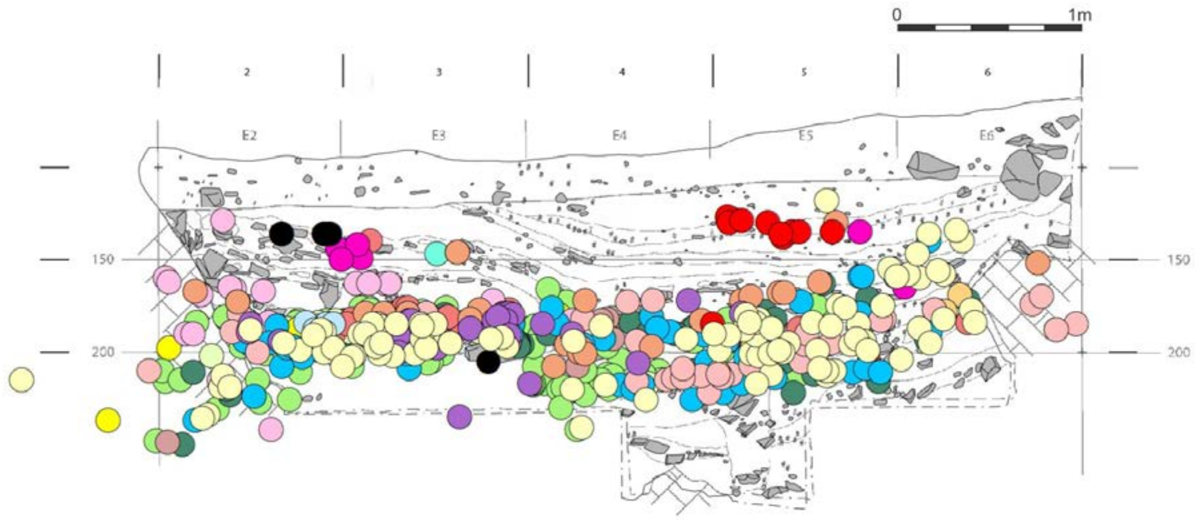

Fig. 8 – Projection of the 26 vessels identified onto Stratigraphic profile no.1. Each colour distinguishes a different vessel.

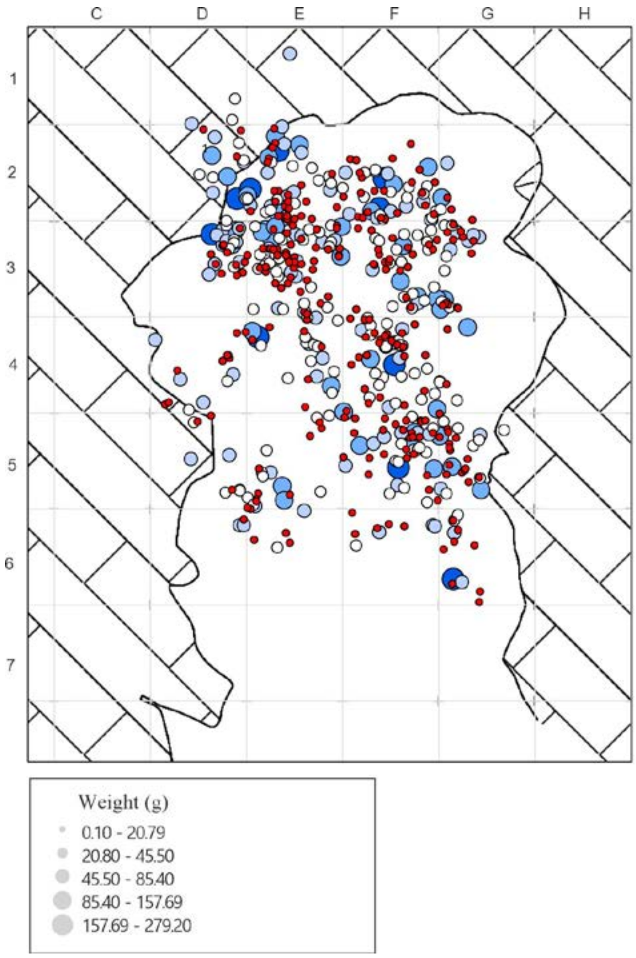

Fig. 9 – Spatial distribution of the 26 vessels. Each sherd's weight (g) is indicated by the size of the dot.

rims are missing and only the lower parts of the vessels are preserved. Regarding rim orientation, 12 of these vessels have an excurved rim, nine of them in the vertical direction. Two of them are curved inside. Six vessels present a prehension element. Three of them belong to the lug category, and the others to the handle category. The majority of the 26 vessels (14 out of 26) lack a surviving base. Eleven of the bases identified are flat, and a single one is rounded.

The vessels found in the Eremita Cave were classified according to their morphological characteristics as cups, pots, bowls, jars, and unidentifiable shapes. Out of the 26 vessels, 11 belong to the cup category, five to the pot category, five to the bowl category, three to the jar category, and two present unidentifiable shapes.

1. *The cups* category encompasses 11 vessels. In terms of shape and decoration, this is the most varied category. The general morphology of the vessels varies, including straight, rounded and carinated profiles. The rims are vertical or curved outwards. Three of the vessels bear no decoration or prehension elements. The linear incised decoration on the rims or lips is characteristic of this category. The main decoration in this category consists of zigzag lines along the rim, diagonal hatches, linear lines, and leaf-like incisions on the body. One of the cups belongs to the category of carinated spherical cups with rounded bases and is decorated with three incised lines running around the body (Fig. 10b).
2. *The pots* category is represented by five vessels, most of which are vertical or slightly curved inward, except for one, which has a rounded body. Most of them have cordons. The cordons

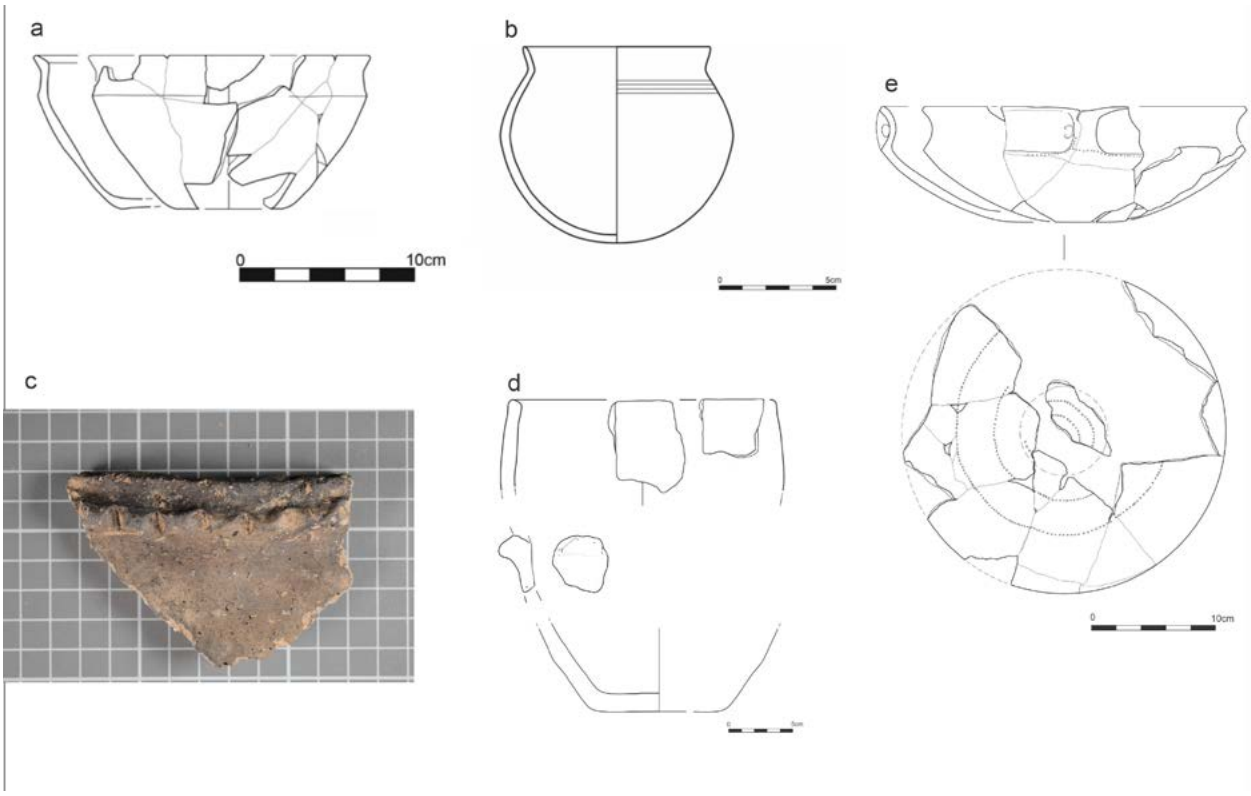

Fig. 10 – The four vessel shape categories identified through this study: bowls (a and e), the second bearing a stamped decoration, globular cups (b), jars (c), pots (d). – (after Derenne 2016: appendix 1: 1; appendix 7: 60–63).

— further decorated with finger impressions or not — are placed under the rim and around the body. In one case, the fingerprint decoration is applied directly to the vase without the addition of clay. In another instance, a lug is applied to the body (Fig. 10d).

3. *The bowls* category includes five vessels. They are all open vessels. Two of them have an S-shaped profile (Fig. 10a). The third one has no decoration at all, while the fourth one is decorated with parallel incisions of blind holes that go all the way around the bowl. It also has a handle that extends from the rim to the carinated part, forming a narrow hole in the shape of a tunnel (Fig. 10e). One of the bowls has fingerprint decoration on the inside, specifically on the lip.
4. *The jars* category is represented by four vessels. Typologically, this category is the most homogeneous. The main characteristic of this group is their vertical or slightly curved profile. Their decoration consists of horizontal alignments of fingerprints under the rim (Fig. 10c), along the body, and on the lip. They have lugs in the form of buttons or a cordon attached to the centre of the body.

Decoration techniques

Seventeen of the 26 vessels are decorated, with fingerprints (n = 7), incisions (n = 7), attached cordon(s) (n = 6) or nail imprints (n = 1). These different decoration types are sometimes combined on the same vase. The remaining nine vessels are undecorated. As for the position of the decoration, they are placed on the rim (n = 6), neck (n = 6), shoulder (n = 6) and body (n = 4). There is only one case of decoration at the base of the vessel.

Regarding the technical aspects of decoration, as Roux (2019) explains, the impression technique consists in pressing a hard object against the clay paste or by pressing the clay paste against a hard object to create the desired pattern. In the present corpus, this technique mostly takes the form of fingerprinting, by adding a cordon of clay around the vessel and then pressing a finger into it to create depressions of approximately 90mm in length, one after the other (Figs 11a and 11c). The fingerprint technique was sometimes applied directly to the vessel without the addition of a cordon of clay (Fig. 11b). A cup was also decorated using the fingerprint technique (Fig. 11d), but on the inside of its bevelled rim. In one case, a small pointy tool was stamped onto a carinated bowl to create lines of small dots (Fig. 12b). One of these lines follows the rim, while the lower part of the body is dotted with four circles, each tapering towards the smallest at the base.

Incision is a type of decoration that is also present on several Eremita Cave vessels. This decoration technique consists in drawing patterns on a vessel, in a linear

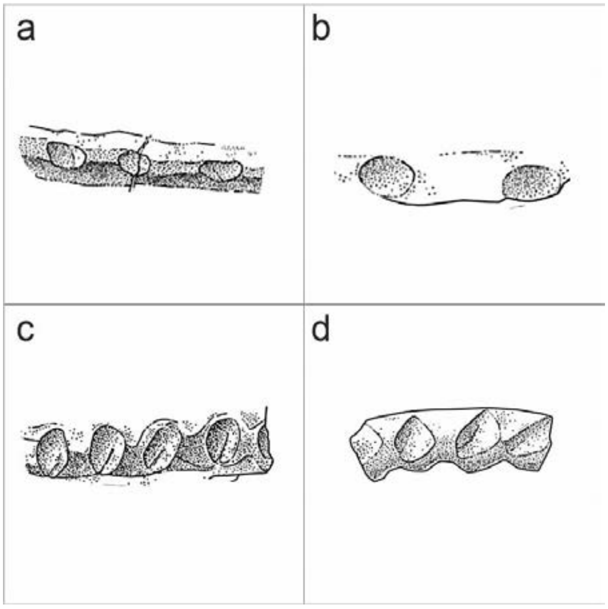

Fig. 11 – Types of fingerprint decoration present in the corpus of the Eremita Cave: Fingerprints applied to the cordon (a, c and d). – Fingerprint applied directly to the vessel (b).

movement, by dragging a tool into its wet or leather-hard paste. It can be performed with different types of tools, in different materials (wood, metal, bone, ceramics, stone, basketry, etc.), and to create different patterns (Roux 2019). Within our corpus, the incisions vary in pattern and position on the vessels. In the case of a globular cup, three lines of incisions were made under the neck, around the body of the vessel (Fig. 12a). Incised zigzag or diagonal hatches on the top of the rim are also present (Figs 12c and 12e). One of the cups presents a line of incised hatches (Fig. 12d), and another cup a line of leaf-shaped incisions (Fig. 12f).

Vessels' chronological sequences

The dating of the vessels is based on the 13 radiocarbon dates and their relationship to the position of the sherds in their respective stratigraphic unit (US). The pottery belongs mainly to the Middle Bronze Age (1625–1325 BC) and to a lesser extent to the Final Bronze Age (1325–800 BC). The results show that 23 vessels, two spindle whorls and four ceramic beads belong to the Middle Bronze Age. The majority of these (n = 18) have a strong relationship with US19. This layer yielded the cremated human bones found at the centre of the cave, bronze artefacts, and a high proportion of 'waste' such as fragmented faunal remains. Two vessels were dated to the Final Bronze Age on the basis of the absolute chronology of US10 and of their typology. One of the vessels, known only from a fragment, lacked information, so its date remains unknown.

Cross-regional comparisons and discussion

The Eremita Cave pottery assemblage is composed of a variety of vessel types in terms of morphological and decorative characteristics. It should be noted, however, that the corpus of pottery from the cave is essentially coarse and simple in form and decoration, and that with the exception of a few specimens, there are no strong and specific characteristics that could be clearly assigned to any cultural sphere. Another drawback for typological comparisons is the small number of publications on pottery from northwestern Italy — highlighting the importance of an assemblage such as the one presented here. The decoration motifs and techniques, however, allow for a certain degree of comparison with other sites in northern Italy and beyond.

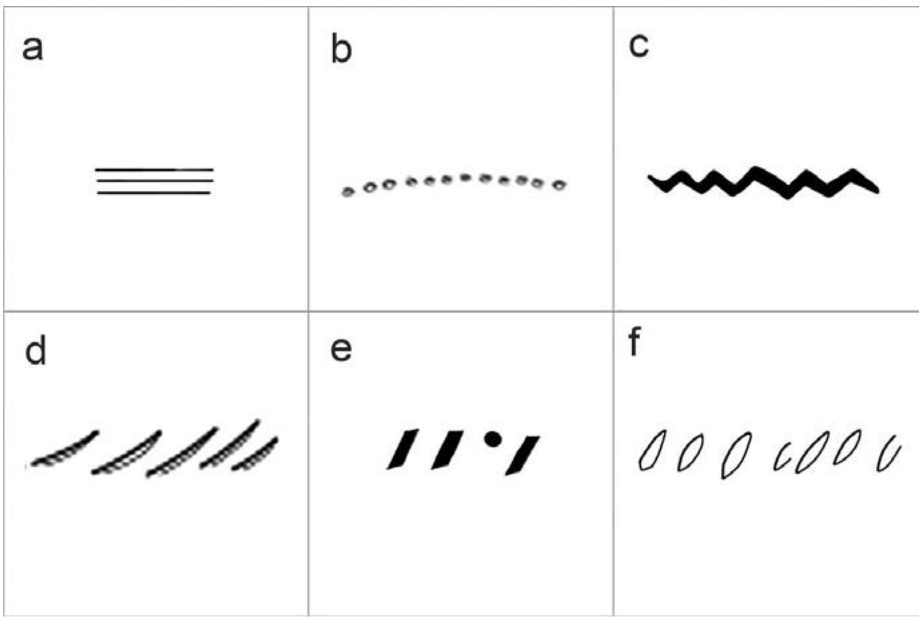

Fig. 12 – Types of decoration found in the Middle and Final Bronze Age corpus of the Eremita Cave: Incised lines (a). – Dotted impressions (b). – Zigzag incision (c). – Diagonal lines incision (d). – Diagonal hatches (e). – Leaf-shaped incisions (f).

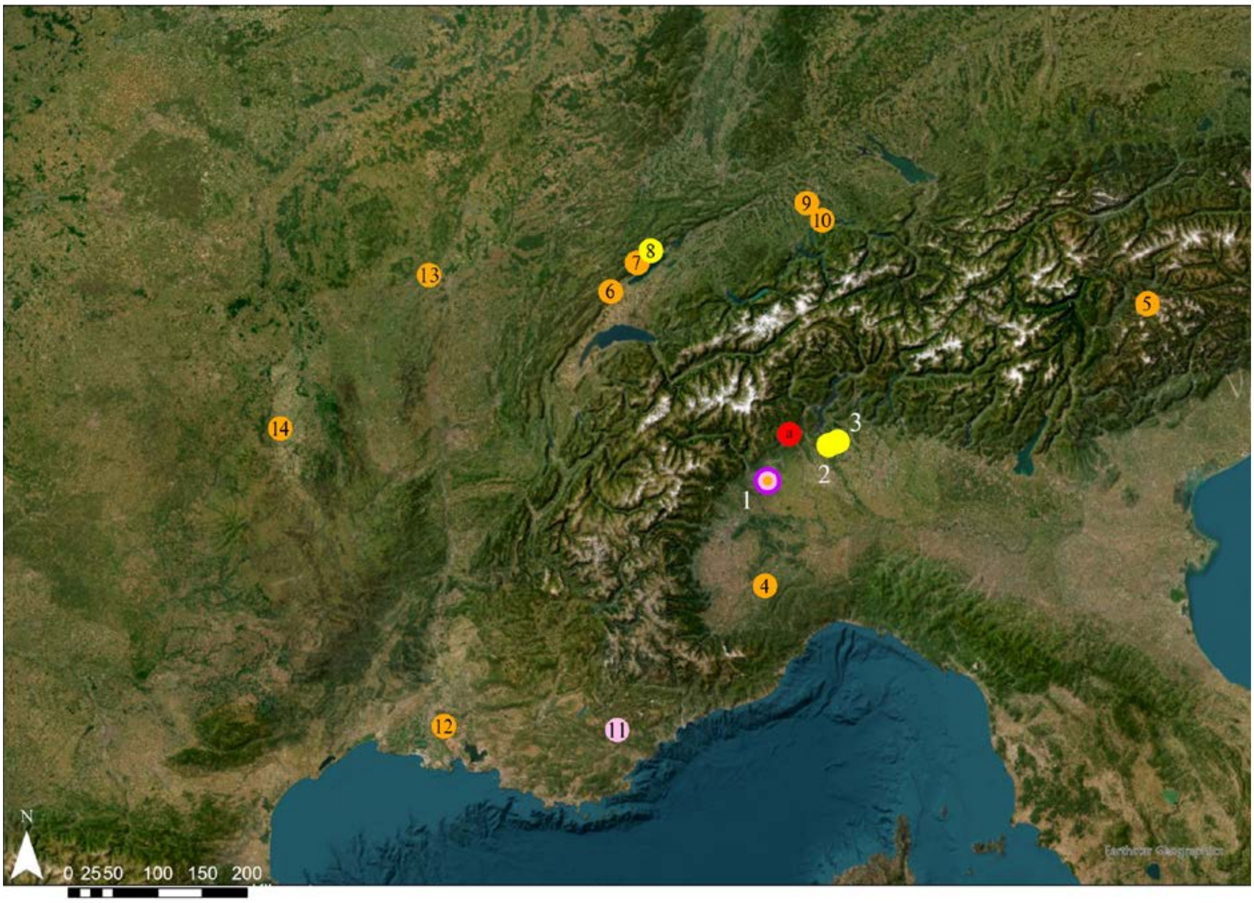

Fig. 13 – Typological comparison of pottery. Each colour corresponds to a type of vessel found in the Eremita Cave: bowls (purple); jars (orange); globular cup (yellow).
a. Eremita Cave (Borgosesia, Vercelli, Italy); 1. Viverone-Vi1 Emissario (Biella, Italy); 2. Golasecca-Sesto Calende (Varese, Italy); 3. Monsorino (Varese, Italy); 4. Alba Site-Saggio C (Piemonte, Italy); 5. Sotciastel (Val Badia, Bolzano, Italy); 6. Rances Champ-Vully (Vaud, Switzerland); 7. Bevaix 'Les Pâquiers' (Neuchâtel, Switzerland), 8. Auvernier (Neuchâtel, Switzerland); 9. Birmensdorf – Stoffel (Zürich, Switzerland); 10. Wädenswil-Vorder-Au (Zürich, Switzerland); 11. Peygros Cave (Mons, France). 12. La Fourbine Cave (Saint-Martin-de-Crau, Bouches-du-Rhône, France); 13. Chassey-Le Camp (Saône-et-Loire, France); 14. Cournon (Clermont-Ferrand, France). – (Base map: Earthstar Geographics).

Based on the morphological characteristics of the corpus, we defined four categories, including the bowl, jar, cup and pot categories. Nineteen vessels belonging to these four categories could not be compared with other contemporary sites due to the aforementioned limitations. Fortunately, a cross-regional comparison with northern Italy, the north of the Alps and southeastern France was still possible. Comparisons are more easily found for the larger vessels of the corpus, which present more specific decoration and general shapes. Two vessels in the bowl category, three in the jar category and two in the cup category can be compared with contemporary sites (Fig. 13).

The bowl category offers three comparisons from Italian and French contexts. A bowl from the Eremita Cave compares with a vessel from the pile-dwelling site of Viverone-Vi1 Emissario (Biella, Italy) (Rubat Borel 2010, fig. 3.8) (Fig. 13, no. 1). Its profile, including the handle, is almost identical to the characteristics of the Viverone example, although the decoration is different, consisting of vertical linear incisions running from the base to the carination (Derenne 2016). Another example corresponding to this bowl type —although lacking the decoration — is found in the Peygros Cave (Mons, Var, France) (Fig. 13, no. 11), not far from the Mediterranean coast (Vital 1999, fig. 7.1). Another bowl from the Eremita Cave also shows similarities with a second bowl from Viverone (Rubat Borel 2010, fig. 3.8), although the decoration is different (Derenne 2016).

The morphological characteristics of three jars from the Eremita Cave can be compared on a larger scale. In particular, the style of decoration — fingerprints on the cordons or on the rim — and the simple types of lugs in the form of buttons were very common within a

wide geographical area at this time. As far as northern Italy is concerned, similar techniques were used on the pottery of Viverone (Rubat Borel 2010, figs 11, 13, 14), at the site of Alba (Piedmont) (Gambari *et al.* 1995, figs 143.10, 144.2) (Fig. 13, no. 4), as well as at the site of Sotciastel (Val Badia, Bolzano) (Fig. 13, no. 5) (Tecchiati 1998, fig. 7). Similarly, Middle Bronze Age pottery from the La Fourbine Cave in Saint-Martin-de-Crau (Bouches-du-Rhône, France) (Fig. 13, no. 12) shares features with the Eremita Cave jars (Lachenal and Vital 2010, tab. 6). The characteristics of the jars from the Eremita Cave are also related to the typological traits of the pottery found at the site of Cournon (Puy-de-Dôme, France) (Fig. 13, no. 14). Although located in the Limagne plain of the Massif Central, this decorated pottery belongs to a very southern *facies* of the Middle Bronze Age: Saint-Vérédème in Languedoc and the lower Rhône valley (Ballut *et al.* 2006).

Decoration techniques and patterns similar to those of the Eremita Cave jars mentioned above can also be compared with pottery from contemporary sites in the northern Alpine regions (*c.* 1600–1500 BC). These include Rances Champ-Vully (Vaud, Switzerland) (Fig. 13, no. 6), Bevaix-Les Pâquiers (Neuchâtel, Switzerland) (Figure 12:7), Birmensdorf-Stoffel (Zürich, Switzerland) (Fig. 13, no. 9), which correspond culturally to the so-called 'Western Tumulus groups' (David-Elbiali and David 2009), and the sites of Wädenswil-Vorder-Au (Zürich, Switzerland) (Fig. 13, no. 10), and Chassey-Le Camp (Saône-et-Loire, France) (Piningre et Vital 2006**)** (Fig. 13, no. 13), which belong culturally to the Rhône culture (David-Elbiali and David 2009). The pottery found in these areas has, among other typological features, straight and recessed necks with flattened and often thickened rims (David-Elbiali and David 2009). Decoration, when present, mostly include finger-impressed cordons placed directly under the rim and horizontal cordons, similar to those found on the jars from the Eremita Cave.

As far as the Late Bronze Age is concerned, among two vessels dated to this period, a globular cup from the Eremita Cave can be compared with three specimens from other sites, one from the site of Auvernier (Neuchâtel, Switzerland) (Fig. 13, no. 8), attributed to the Hallstatt B3 phase, and the other two, from Golasecca-Sesto Calende (Varese, Italy) (Fig. 13, no. 2) and Monsorino (Varese, Italy) (Fig. 13, no. 3), attributed to the 'Golasecca I' phase. All three examples are associated with the Final Bronze Age (David-Elbiali 2013), and in particular with the 9th century BC (Derenne 2016), which is consistent with the absolute chronology of US10.

The petrographic analysis undertaken of the corpus shows that the raw material that was used as an ingredient for the manufacture of the vessels was sourced from a distance of 1 to 5 kilometres around the cave (Igrishta 2023; Igrishta *et al.,* this volume). The pottery therefore was not imported, and the typological similarities with vessels from other sites should be seen as the result of a transfer of ideas or traditions rather than of import. These cultural influences were the result of contact between the northern Alps and southern France on the one hand and northern Italy on the other, from the beginning of the Middle Bronze Age (David-Elbiali and David 2009). J. Vital (1999) pointed out the likelihood that, during this period, decorative themes typical of Italian groups were introduced into the pottery styles of southern France (Provence, Languedoc, Grands Causses).

This highly diverse range of reference sites showing similarities with the Eremita Cave pottery, including cave sites (e.g., La Fourbine Cave, Saint-Martin-de-Crau, France), pile-dwellings (e.g., Viverone-Vi1 Emissario, Italy) and terrestrial sites (Sotciastel, Val Badia, Italy), reflects the dynamics of the circum-Alpine cultural contacts during the Middle Bronze Age, around 1600–1500 BC. This period saw a renewal of cultural entities, a process that impacted the Italian peninsula to a large extent (De Marinis 1981). The fact that these cultural contacts involved large areas, such as the Alpine foothills and highlands, could be an indicator of increased territorial pressure, particularly in relation to the development of pastoral practices, as suggested by Ballut *et al.* (2006).

Conclusions

This article explored the typological features of the Middle and Final Bronze Age pottery from the Eremita Cave, its relationship with the stratigraphic context of the site, and their connections with other sites, located both close-by and situated north or west of the Alps. This analysis gave us an idea of the pottery styles and cultural exchanges of the communities living in the Lower Sesia Valley during the second half of the 2nd millennium BC and the beginning of the 1st millennium BC.

The excavation of the Eremita Cave yielded a total of 2,982 pottery sherds, for a weight of 35.5kg. A set of 858 sherds weighing approximately 29.1kg was selected to form groups to determine the minimum number of vessels. The ceramic fragments were then classified into subgroups according to their raw material and typological characteristics, as well as refittings. This determination of the macro-paste, combined with the morphological study carried out on a large number of sherds, made it possible to identify the 26 vessels presented in this study and to characterize them typologically.

This assemblage (n = 26) presented a variety of pottery shapes, with 11 cups, five pots, five bowls, four jars, and one vessel of an unidentifiable morphology. The well-individualized stratigraphic distribution of these vessels, combined with the radiocarbon measurements obtained for the US they belonged to, confirms their attribution to the Middle Bronze Age (1625–1325 BC, n = 23) and the Final Bronze Age (1325–800 BC, n = 2). Their decorative styles, made with simple techniques based on linear incisions and circular or oblong impressions, offer opportunities for comparisons with other sites in northern Italy and in regions located north and west of the Alps.

Altogether, this typological study offers indications about the local characteristics of pottery from a cave occupation site associated with cremated bones and evidence for wider cultural influences within a radius of over 350km around this site. In conclusion, the ceramic assemblage from the Eremita cave enriches and opens new questions in the context of the Bronze Age in northwestern Italy and beyond.

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Petrographic study of Middle and Final Bronze Age (1625–800 BC) pottery from Eremita Cave (Borgosesia, Vercelli, Italy): inferences on pottery production and exploitation of natural resources

Kaltrina Igrishta, Delia Carloni and Marie Besse

Located on the western slope of Mount Fenera, the Eremita Cave overlooks the Alpine Sesia Valley in Piedmont region (Italy). Ten years of excavation (2012–2021) revealed that the cave was frequented for burial purposes during the Middle and Final Bronze Age (1600–800 BC) and yielded a ceramic assemblage composed of 2982 sherds. The petrographic study regarded 28 samples, selected by taking into account pottery typology, relative chronology, surface and core colours as well as macroscopic features of pastes. The analysis aimed at investigating paste composition and exploitation of natural resources. Pottery from Eremita Cave displays the characteristics of five fabrics, mainly discriminated by aplastic inclusions (quartz, granite-granodiorite, pyroxenite, volcanic rocks). These findings allowed to draw inferences on the Middle and Final Bronze Age pottery production in the Lower Sesia Valley and on the exploitation of local natural resources by human groups.

Keywords: Eremita Cave, Bronze Age, pottery raw materials, archaeometry

Située sur le versant ouest du Mont Fenera, la Grotte de l'Eremita surplombe la vallée alpine de Sesia dans la région du Piémont (Italie). Dix années de fouilles (2012–2021) ont révélé que la grotte était fréquentée à des fins funéraires au cours de l'âge du Bronze moyen et final (1600–800 av. J.-C.) et ont livré un assemblage de céramiques composé de 2982 tessons. L'étude pétrographique a porté sur 28 échantillons, sélectionnés en tenant compte de la typologie des poteries, de la chronologie relative, des couleurs de surface et de l'intérieur ainsi que des caractéristiques macroscopiques des pâtes. L'analyse visait à étudier la composition de la pâte et l'exploitation des ressources naturelles. Les poteries de la Grotte de l'Eremita présentent les caractéristiques de cinq pâtes, caractérisées principalement par des inclusions aplastiques (quartz, granite-granodiorite, pyroxénite, roches volcaniques). Ces résultats ont permis de tirer des conclusions sur la production de poteries de l'âge du Bronze moyen et final dans la basse vallée de Sesia et sur l'exploitation des ressources naturelles locales par les groupes humains.

Mots-clés : Grotte de l'Eremita, âge du Bronze, matières premières de poterie, archéométrie

Fenera Dağı'nın batı yamacında yer alan Eremita Mağarası, Piedmont bölgesindeki (İtalya) Alp Sesia Vadisi'ne bakmaktadır. On yıl süren kazı çalışmaları (2012-2021), mağaranın Orta ve Son Tunç Çağı'nda (MÖ 1600-800) ölü gömme amacıyla kullanıldığını ve 2982 parçadan oluşan bir seramik topluluğu ortaya çıkardığını göstermiştir. Petrografik çalışmada, seramik tipolojisi, göreceli kronoloji, yüzey ve çekirdek renklerinin yanı sıra hamurların makroskopik özellikleri de dikkate alınarak seçilen 28 örnek değerlendirilmiştir. Analiz, hamur bileşimini ve doğal kaynakların kullanımını araştırmayı amaçlamıştır. Eremita Mağarası'ndan elde edilen çanak çömlekler, esas olarak aplastik içeriklerle (kuvars, granit-granodiyorit, piroksenit, volkanik kayaçlar) ayırt edilen beş dokunun özelliklerini sergilemektedir. Bu bulgular, Aşağı Sesia Vadisi'ndeki Orta ve Son Tunç Çağı çanak çömlek üretimine ve yerel doğal kaynakların insan grupları tarafından kullanımına dair çıkarımlar yapılmasına olanak sağlamıştır.

Anahtar Kelimeler: Eremita Mağarası, Tunç Çağı, çanak çömlek hammaddeleri, arkeometri

Introduction

This paper presents the results of the petrographic study conducted on the pottery found at Eremita Cave, located in Northern Italy, Piedmont region, in the territory of the municipality of Borgosesia. Eremita Cave constitutes an important archaeological context for the analysis of social and ideological development in the Middle and Final Bronze Age in the southern Alpine region of Central Europe.

This work focuses on how people/potters produced ceramic containers in general and how they procured and used raw materials in particular, contributing to the research on the wider social, cultural and environmental contexts of Bronze Age societies. Raw materials selection and use provide valuable information on various aspects of ancient lifeways and cultural identities (Albero 2014; Arnold 1985; 2018; Orton *et al.* 1993; Rice 1987; Roux 2019; Shennan 2013). As Shepard (1965) notes, the importance of the potter's knowledge of materials is obvious. The choice of materials sets the boundaries within which the potter must work, and the status of the craft must be judged within these boundaries. In addition, the potter's choice of materials and the way he/she uses them, as well as

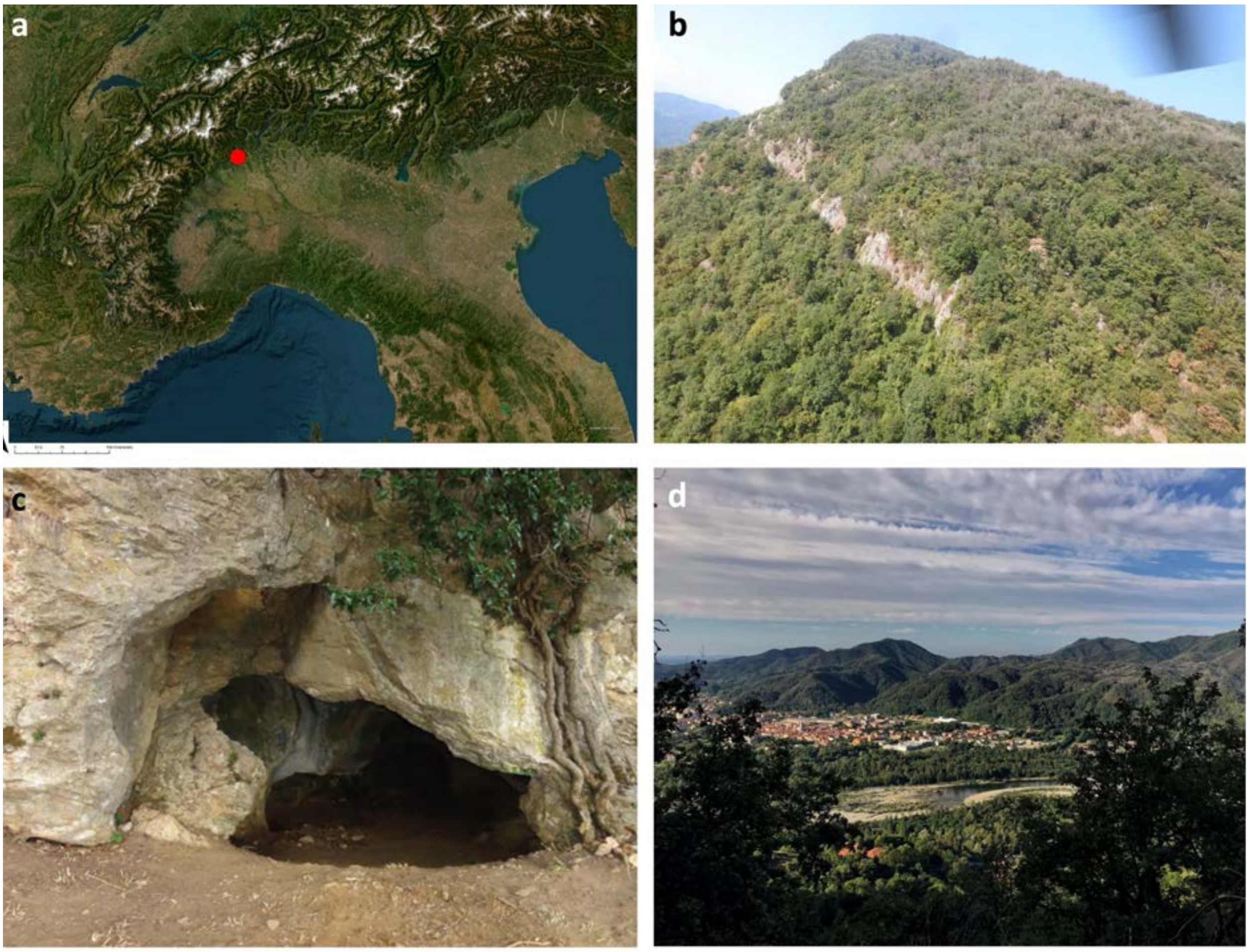

Fig. 1 – The Eremita Cave archaeological context: Location in the north of Italy with respect to Alps (a). – The western flank of Mount Fenera where the cave opens (b). – The cavity entrance before the excavation (c). – View from the Eremita Cave to the Lower Sesia Valley (d). – (a: satellite photo adapted from and courtesy of Google Earth; b-c: after Derenne 2016: figs. 1, 2; fig. d: photo by Bastien Gallay).

the form and style of decoration, are trademarks – our often powerful means of locating centres of production (e.g., Arnold 2018). The study of each of these areas provides valuable information on different but related aspects of human behaviour (Stoltman and Mainfort 2002).

The analysis of the pottery found at the Eremita Cave is carried out using petrography, a technique that consists in the systematic examination of ceramic pastes and allows to classify vessels' remains based on their compositions and the effects of the manufacturing processes (Degryse and Braekmans 2016; Quinn 2013; 2022; Whitbread 2001). The characteristics of the clay matrix (e.g., homogeneity/heterogeneity, colours, optical behaviour, b-fabrics), of the voids (shape, size and orientation), and of the inclusions (e.g., type, roundness/angularity, sphericity degree, and particle-size distribution) indicate how the raw material has been collected and the *chaîne opératoire* followed to make the pot (Arnold 1985; Balfet 1981; Creswell 1976; 1983; 1996; Dietler and Herbich 1994; Gallay 1992; Gosselain 1992; Latour and Lemonnier 1994; Lemonnier 1983; 1992; 1993; Leroi-Gourhan 1964; Longacre 1991; Quinn 2013; 2022; Roux 2017; 2019; Sigaut 1994).

Archaeological background

Eremita Cave

The Eremita Cave (Fig. 1a) known as "*Grotta dell'Eremita*", or as it is found in local traditions "*Tana dell'Armittu*" (Besse and Viola 2013a) opens on the western flank of Mount Fenera (Fig. 1b) and extends for 30m^2 (Fig. 1c). Its entrance overlooks the Alpine Sesia Valley in Piedmont region (Italy). Located at an altitude of 598m a.s.l., it can be reached by following the so-called 'Strada dei Buoi' path and the one leading to the ancient church of San Quirico (Fig. 1d) (Derenne 2016). Like most of the other caves in the massif, it is formed in the 'San Salvatore' dolomitic sheet (Bini and Zuccoli 2005) and represents a single open compartment inside the dolomitic layers.

Mount Fenera

Mount Fenera (899m) is an isolated massif located on the southern margin of the Sesia River, on its left bank. It straddles the Piedmont provinces of Novara and Vercelli, which, from a geographical point of view, are made up of three main areas: the Alpine reliefs, the Italian Pre-Alps and finally the alluvial plains (Besse and Viola 2013a). The winding course of the Sesia River crosses these three geographical areas. The river originates from the Monte Rosa Glacier, it runs along the low hills of Gattinara and Romagnano Sesia and finally reaches the plain, where it flows into the Po River at Casale Monferrato (Besse and Viola 2013a).

The Mount Fenera massif accounts for about seventy caves, many of which contain traces of human occupation, dating from the Middle Palaeolithic to the Late Middle Ages (Gambari 2005). The massif could thus have been a place of passage for the prehistoric populations during their transalpine travels. This consideration is not surprising, considering its location, at the entrance of several valleys leading to numerous hills giving access to the Upper Rhône Valley, and its specific geological characteristics (Besse and Viola 2013b).

Neolithic materials were discovered on the terrace of Fenera San Giulio (414m a.s.l.) and in the cave of Riparo del Belvedere (662m a.s.l.). Chalcolithic materials were found in the caves of Uomo libero (620m a.s.l.), Ciotarun (635m a.s.l.) and Ciota Ciara (675m a.s.l.) – the latter better known for its Middle Palaeolithic remains – as well as on the Montrigone hill. The terrace of Castello di Robbiallo (354m a.s.l.) shows evidence of Chalcolithic and Early Bronze Age occupation, while the Tana della Volpe Cave (661m a.s.l.) contains only Early Bronze Age materials. Finally, in the Laghetto Cave (701m a.s.l.), Early and Middle Bronze Age remains were uncovered (Besse and Viola 2013a).

History of research

The presence of an archaeological deposit in the cave was first detected in the 1980s by the *Gruppo archeo-speleologico di Borgosesia (GASB)* (Besse and Viola 2013b), which opened test trenches. Later, in 2012, a test trench was excavated by the *Laboratoire d'archéologie préhistorique et anthropologique* of the University of Geneva headed by one of us (M. B.), who uncovered, besides ceramic and bone remains, a metal pin and spiral beads (Fig. 2), leading to further excavations from 2013 in the northern part of the cave. The digging operations undertaken in the cave combined two essential approaches: stratigraphic and planimetric. During the numerous excavation campaigns carried out between 2013 and 2021, structures and a number of 2982 pottery sherds, fauna, human cremation remains, bronze objects and flint were discovered. All

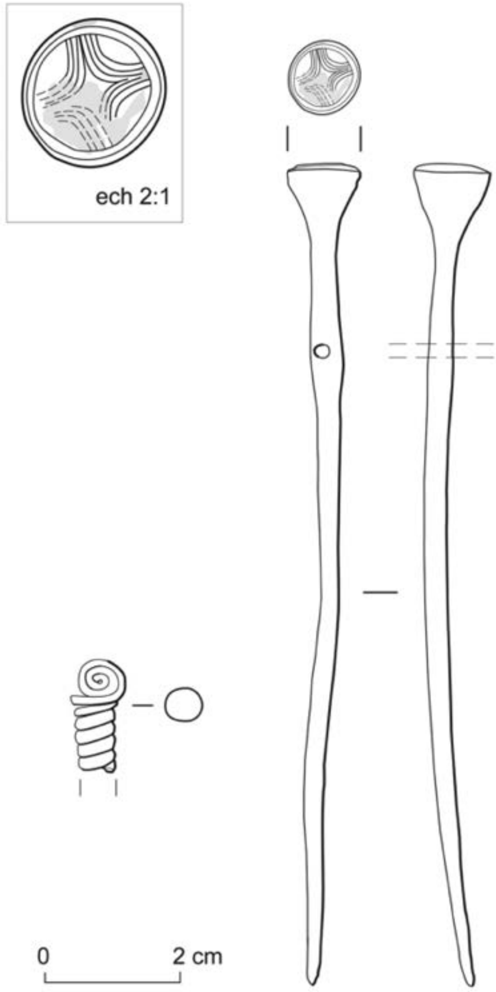

Fig. 2 – Bronze spiral pin and ornament from Eremita Cave. – (after Besse *et al.* 2014: fig. 6).

the findings were assigned to a specific stratigraphic unit (US). The Eremita Cave was excavated up to the depth of 120cm in 2013 and to the depth of 198.4cm in 2021. Acquired data highlight that the cave was frequented for burial purposes during the Middle (1625–1325 BC) and Final Bronze Age (1250–800 BC) (Besse and Viola 2013a; Besse *et al.* 2014; Derenne *et al.* 2020; Rubat-Borel *et al.* 2022). The chronology of human use was determined according to obtained radiocarbon dates (16 samples analysed by the Swiss Federal Institute of Technology of Zürich, Fig. 3) and pottery typology (Derenne *et al.* 2020).

Geological setting

The complexity of Piedmont region's geology mainly results from the Paleogene to Neogene Alpine orogenesis, originated by the collision of the European and Palaeo-Adriatic continental margins (Handy *et al.* 2010; Piana *et al.* 2020; Schmid *et al.* 1996, 2004). The study area of the present work is occupied by the Palaeo-Adriatic

Sample code	Sample number	Dating BP	2 sigma (prob. 95.4%)	Material
BE15-F5-prCH4	ETH-64659	2794 ± 27 BP	1013–850 cal BC	charcoal
BE14-E4-prCH14	ETH-64658	3323 ± 28 BP	1684–1527 cal BC	charcoal
BE13-E2-prCH6	ETH-64656	3334 ± 28 BP	1689–1530 cal BC	charcoal
BE14-E4-prCH10	ETH-64657	3404 ± 28 BP	1767–1627 cal BC	charcoal
BE15-F5-prCH2	ETH-104336	2688 ± 22 BP	895–806 cal BC	charcoal
BE16-F3-prCH5	ETH-104337	3159 ± 22 BP	1497–1403 cal BC	charcoal
BE18-F3-prCH105	ETH-104338	3294 ± 25 BP	1626–1507 cal BC	charcoal
BE18-F3-prCH106	ETH-104339	3318 ± 24 BP	1664–1527 cal BC	charcoal
BE18-G5-prCH111	ETH-104340	3475 ± 22 BP	1882–1701 cal BC	charcoal
BE18-F4-prCH118	ETH-104341	3207 ± 24 BP	1520–1427 cal BC	charcoal
BE18-F5-prCH131	ETH-104342	3318 ± 22 BP	1660–1528 cal BC	charcoal
BE18-F5-prCH136	ETH-104343	3363 ± 25 BP	1741–1566 cal BC	charcoal
BE18-G3-prCH137	ETH-104344	3275 ± 25 BP	1616–1501 cal BC	charcoal

Fig. 3 – Radiocarbon dates obtained for the various layers of Eremita Cave. – (Calibration with OxCal 4.4.4 [Bronk Ramsey 2021], based on the IntCal20 calibration curve [Reimer *et al.* 2020]).

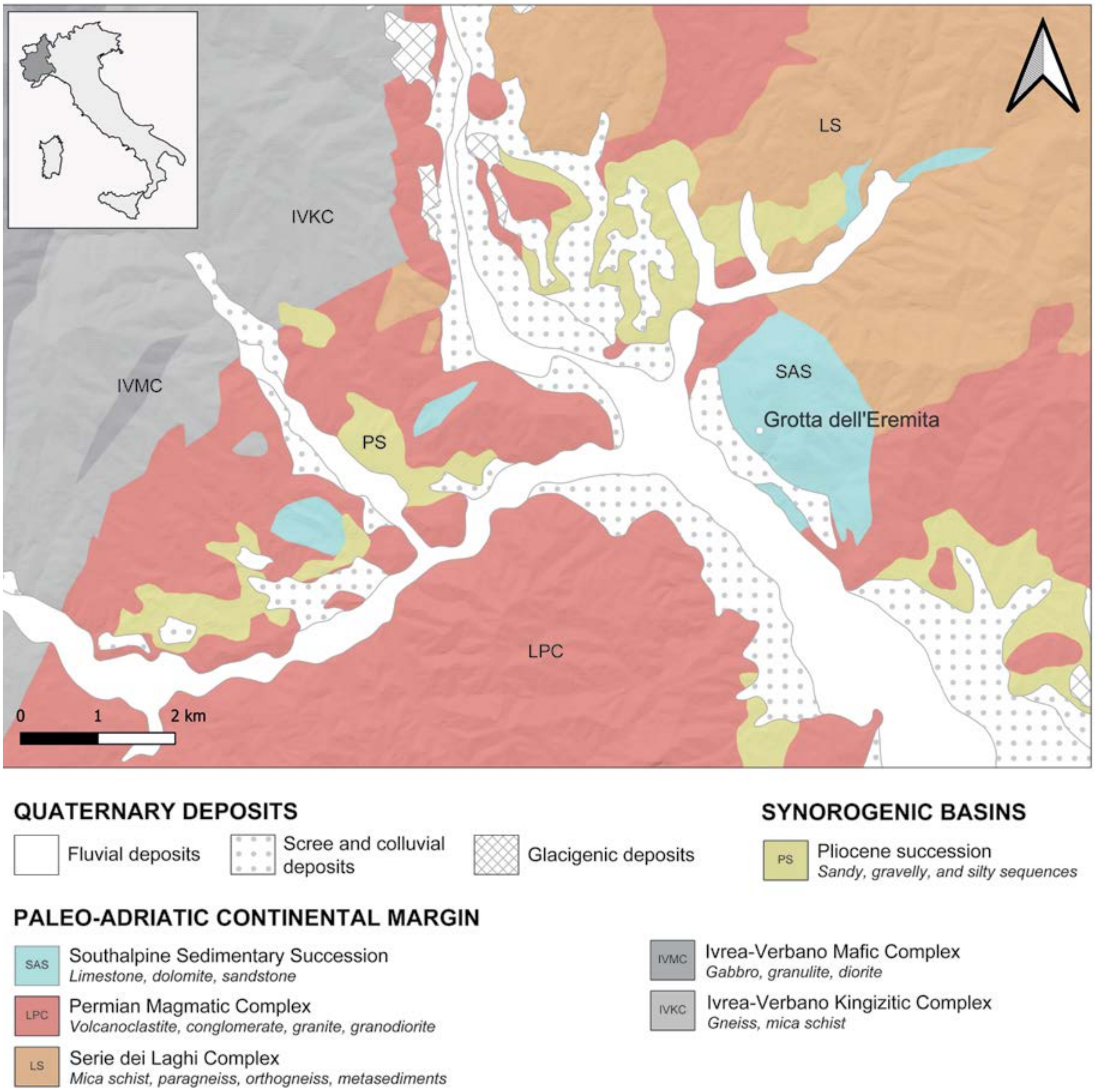

Fig. 4 – Geotectonic map of the Lower Sesia Valley with location of the Eremita Cave. – (Data source: GeoPiemonte https://www.geoportale.piemonte.it/cms/; design: Delia Carloni).

margin, and specifically, by the Southalpine Domain geologic unit. This unit consists of Variscan and pre-Variscan metamorphic rocks of granulite-amphibolite facies, derived from sedimentary, felsic and mafic igneous protoliths (Ivrea-Verbano Complexes, Serie dei Laghi Complex), intruded by granitoids and gabbros of Permian age (Permian Magmatic Complex, sub-unit 'Graniti dei Laghi Complex') and covered by both volcanic and volcaniclastic deposits (Permian Magmatic Complex, sub-unit 'Porfidi Quartziferi Complex') and Triassic-Jurassic sediments (Southalpine sedimentary succession) (Piana *et al.* 2017; 2020). Figure 4 shows the outcropping areas of these various rock bodies in the Lower Sesia Valley. Mount Fenera, where the Eremita Cave opens, is part of the Southalpine sedimentary succession and has the double peculiarity of being the only massif composed of dolomites and limestones in this part of the valley and of being located near two tectonic lines, the Cremosina line and the Colma line (Fantoni *et al.* 2005a; 2005b). This explains the development of important karstic phenomena within it (Derenne 2016). Most of the caves in the Mount Fenera massif were formed in the Miocene (Bini and Zuccoli 2005), before undergoing modifications and enlargements during the climatic changes of the Pliocene-Pleistocene transition (Berruto 2011). The geological sequence of the Mount Fenera is placed on the Serie dei Laghi Complex and the Permian Magmatic Complex and consists of multiple successions of sandstone, carbonate rocks, and breccias (Fantoni *et al.* 2005b). Finally, the Quaternary cover of the study area is composed of glacigenic, scree and colluvial deposits, which are eroded and reworked by the Sesia River, thus contributing to the fluvial deposits formed on the banks of its winding course. Glacigenic deposits include a great variety of lithoclasts derived from various complexes of the Palaeo-Adriatic margin (Piana *et al.* 2017; 2020).

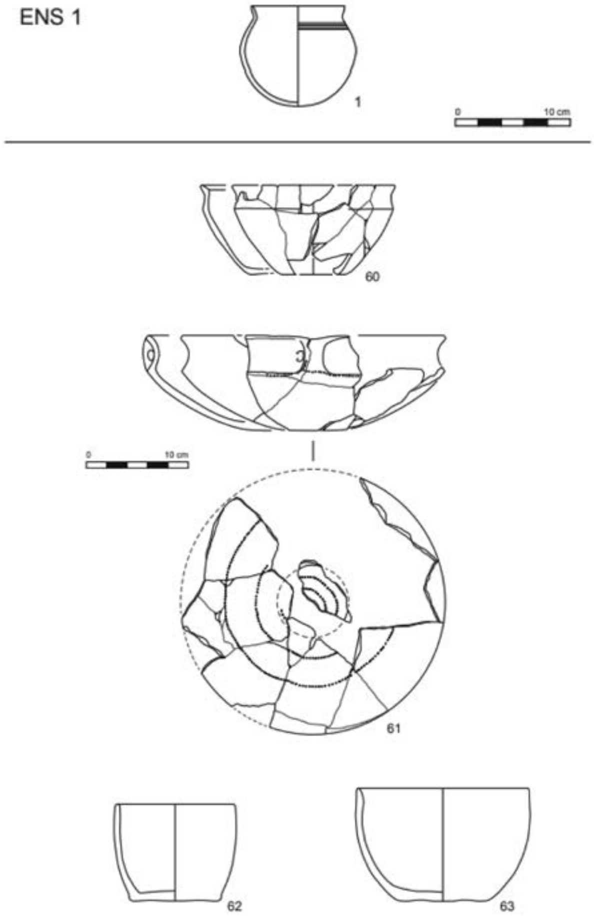

Fig. 5 – Important shapes from Eremita Cave: small globular vessel with flared rim dating to the Final Bronze Age (no. 1), segmented profile bowls (nos 60, 61) and simple profile vessels (nos 62, 63) dating to the Middle Bronze Age – (after Derenne 2016: appendix 1: 1; appendix 7: 60–63).

Materials and methods

Materials

The archaeological finds from the Eremita Cave are under the care of the *Museo di Archeologia e Paleontologia Carlo Conti* in Borgosesia, Vercelli, Italy. The ceramic assemblage from the Eremita Cave comprises materials from the Middle and Final Bronze Age (1625–800 BC) and accounts for 2982 pottery sherds. Five reconstructed vessels are of particular importance (Fig. 5). The diagnostic sherds (rim, base, handle, carination, decoration) constitute 13% of the corpus, compared to the non-diagnostic pottery sherds, whose percentage is 87%, in the proportion of 297 diagnostic sherds versus 1997 body fragments. A number of 701 sherds are not counted as a single sherd because they refit with other diagnostic or non-diagnostic sherds. Out of the 297 diagnostic sherds, 159 are rim fragments, 36 are bases, 21 are vertical or lug-shaped handles, 16 are carinated sherds, 54 are sherds with decoration (cordon, fingerprint, incised dots, etc.), 3 profile sherds and 8 pieces that could belong either to bases or carinated body fragments.

The petrographic study regarded 28 samples, selected by taking into account pottery typology, relative chronology, surface and core colours as well as macroscopic features of pastes. The set of 28 sampled pottery sherds included 27 samples dating to the Middle Bronze Age (1625–1325 BC) and 1 to the Final Bronze Age (1250–800 BC) (Fig. 6).

Methods

The petrographic description and classification of the fabrics were carried out by polarized-light microscopy (OM). The analysis was performed at the University

Sample	Inventory no.	Area	Orientation	Macropaste no.	Chronology
GE01	Rem-043 (sherd BE13-E2-77)	Lower part of the vessel	Vertical section	1	Middle Bronze Age
GE02	Rem-067 (sherd BE13-E2-20)	Lower part of the vessel	Vertical section	2	Middle Bronze Age
GE03	Rem-049 (sherd BE14-E3-284)	Lower part of the vessel	Vertical section	3	Middle Bronze Age
GE04	Rem-024 (sherd BE13-D3-179)	Rim	Vertical section	4	Middle Bronze Age
GE05	IC-001 (sherd BE13-E2-144)	Body	Vertical section	5	Middle Bronze Age
GE06	Rem-042 (BE14-E3-740)	Body	Vertical section	6	Middle Bronze Age
GE07	Rem-029 (sherd BE14-E4-133)	Body	Oblique section	6	Middle Bronze Age
GE08	BE15-G5-13	Body	Section	7	Middle Bronze Age
GE09	Rem-016 (sherd BE14-E4-147)	Body	Oblique section	8	Middle Bronze Age
GE10	Rem-009 (sherd BE13-D3-185)	Lower part of the vessel	Oblique section	8	Middle Bronze Age
GE11	Rem-041 (sherd BE13-E3-584)	Body	Section	8	Middle Bronze Age
GE12	Rem-054 (sherd BE13-E3-298)	Lower part of the vessel	Vertical section	9	Middle Bronze Age
GE13	BE18-G4-72	Body	Section	9	Middle Bronze Age
GE14	BE21-F2-514	Body	Vertical section	8	Middle Bronze Age
GE15	BE21-G5-180	Body	Horizontal section	6	Middle Bronze Age
GE16	BE21-F3-679	Body	Oblique section	8	Middle Bronze Age
GE17	Rem-002 (sherd BE13-E3-124)	Lower part of the vessel	Vertical section	2	Middle Bronze Age
GE18	Rem-066 (sherd BE14-D5-176)	Upper part of the vessel	Vertical section	8	Middle Bronze Age
GE19	Rem-022 (sherd BE13-E3-113)	Lower part of the vessel	Vertical section	8	Middle Bronze Age
GE20	BE14-D3-267	Upper part of the vessel	Vertical, but not preserved	8	Middle Bronze Age
GE21	Rem-037 (sherd BE13-D2-20)	Body	Section	8	Middle Bronze Age
GE22	Rem-065 (sherd BE20-F2-265)	Lower part of the vessel?	Vertical section	8	Middle Bronze Age
GE23	Rem-084 (sherd BE21-F4-593)	Body	Horizontal section	8	Middle Bronze Age
GE24	Rem-087 (sherd BE21-F3-782)	Body	Section	8	Middle Bronze Age
GE25	BE21-F4-620	Body	Section	2	Middle Bronze Age
GE26	Rem-044 (sherd BE14-E4-112)	Body	Oblique section	8	Middle Bronze Age
GE27	IC-002 (sherd BE15-F5-5)	Body	Vertical section	2	Final Bronze Age
GE28	BE15-G6-16	Rim	Vertical section	10	Middle Bronze Age

Fig. 6 – List of ceramic samples selected for the petrographic study.

Fabric groups	Sample	Chronology	Dominant inclusions 50–90%	Frequent–Common 15–50%	Few–Rare 0.5–15%	Clast %	Matrix %	Voids %	GSD
Fabric I	2 samples: GE02, GE07	Middle Bronze Age	quartz	granite, biotite	muscovite, plagioclase, quartzite	20	75–77	3–5	BI
Fabric II	1 sample: GE08	Middle Bronze Age		granite with biotite, quartzite, quartz	plagioclase, pyroxenite, muscovite	20	70	10	BI
Fabric III	12 samples: GE04, GE05, GE10–GE14, GE17, GE19, GE25, GE26, GE28	Middle Bronze Age		granite biotite and granodiorite with biotite or horn-blende, plagioclase, biotite	muscovite, quartz, hornblende, quartzite, gneiss with quartz and feldspar, sandstone, mica schist, volcanic rock, mudstone	10–34	65–87	1–5	U, BI, TRI, P
Fabric IV	10 samples: GE09, GE15, GE16, GE18, GE20, GE21, GE22, GE23, GE24, GE27	Middle and Final Bronze Age	granite with biotite, granodiorite with biotite or hornblende	biotite, quartz, muscovite	plagioclase, microcline, hornblende, volcanic rock, mudstone	15–40	57–82	1–5	U, BI, TRI, P
Fabric V	3 samples: GE01, GE03, GE06	Middle Bronze Age	granite	quartz	quartzite, bio-tite, muscovite, plagioclase, microcline, metapelite, orthopyroxene, pyroxenite	26–35	63–68	2–7	U, BI

Fig. 7 – Summary of the fabric characteristics.

of Geneva, using a Leica Leitz DM-RXP polarized-light microscope. The main petrographic characteristics of the ceramic paste (matrix, voids, inclusions) were reported according to the guidelines by Quinn (2013; 2022). The classification of fabrics in this study is mainly based on the type and morphometry of aplastic inclusions, which revealed to have a high discriminatory potential in the classification of prehistoric pottery pastes and to play a considerable role in fabric classification (Brunelli *et al.* 2013; Cannavò and Levi 2018; Day *et al.* 2011; Montana 2020; Salanova *et al.* 2016). Focusing on the characteristics of clasts further revealed to be particularly beneficial in Alpine contexts, where outcropping geological units consist of complex lithological assemblages and sequences, and where Quaternary sediments are dominated by chaotic morphometry and modal distribution (Carloni *et al.* 2022, 2023; Convertini 1997; Di Pierro and Martineau 2002; Maggetti 2009; Nungässer and Maggetti 1992; Stapfer *et al.* 2019).

Results

Polarized-light microscopy allowed to estimate the percentage of matrix, inclusions and voids and to define five ceramic fabrics. Figure 7 shows some criteria adopted in order to distinguish five pottery fabrics among the 28 samples.

Fabric I: Quartz

This fabric (Fig. 8a) describes two samples of Middle Bronze Age chronology. Its groundmass is homogeneous or heterogeneous and optically active with a reddish-brown colour. B-fabric features occur in only one sample and consist of coupled striated and elongated domains (GE02). The shape of the voids is channel-like and size varies from micro to macro with a random orientation. The dominant presence of quartz characterizes Fabric I. Quartz particles are silt- or sand-sized and randomly oriented; their shape is equant with sub-rounded and sub-angular edges. In addition to quartz, this fabric is characterized by sand-sized inclusions of biotite and granite with rounded to sub-angular edges. Furthermore, few-rare muscovite, plagioclase and quartzite inclusions are also documented. Their shape is equant or elongate, while the edges are rounded to angular. The grain-size distribution for Fabric I is bimodal.

Fabric II: Granite, quartzite and pyroxenite

This fabric (Fig. 8b) features only one sample dating to the Middle Bronze Age. The groundmass is homogeneous and optically active with a reddish-brown colour. It has channel-like voids varying in size from 1 to 10mm, and randomly oriented vughs

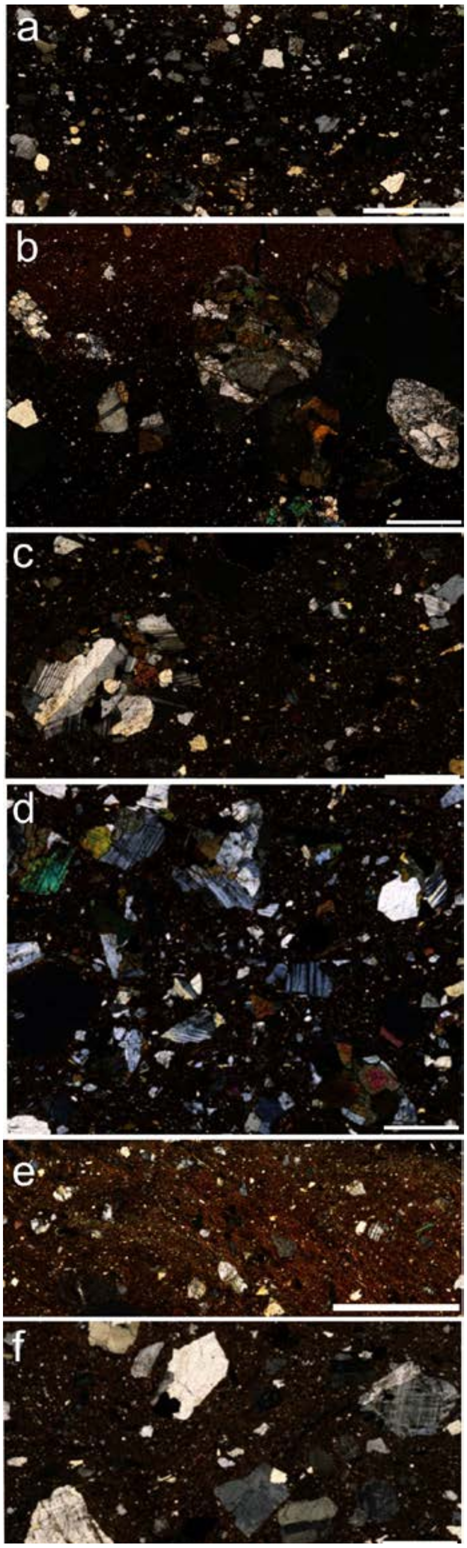

Fig. 8 – Microphotograph showing the characteristics of: Fabric I; GE02, Middle Bronze Age, cross-polarized light (a). – Fabric II; GE08, Middle Bronze Age, cross-polarized light (b). – Fabric III; GE13, Middle Bronze Age, cross-polarized light (c). – Fabric IV; GE16, Middle Bronze Age, cross-polarized light (d). – Fabric IV; GE27, Final Bronze Age, cross-polarized light (e). – Fabric V; GE06, Middle Bronze Age, cross-polarized light (f). – The length of the white bar is 2mm.

are also documented. With reference to inclusions, this fabric is characterized by randomly oriented silt to sand particles and an equant and elongate shape of inclusions of granite with biotite, quartzite, and quartz with sub-rounded to sub-angular edges. Fabric II also contains poorly sorted inclusions of plagioclase, muscovite and pyroxenite in equant or elongate shape with sub-rounded, sub-angular and angular edges. The particle size distribution is bimodal.

Fabric III: Granite and granodiorite

This fabric (Fig. 8c) is represented by 12 Middle Bronze Age samples. The ceramic groundmass is homogeneous or heterogeneous, brownish-coloured and optically active. B-fabric features are rare and consist of coupled striated and elongate domains (GE10). Voids are channel-like in shape, they range in size from 0.04 to 1.4mm and are randomly, subparallel or parallel oriented. The occurrence of intrusive rocks characterizes this fabric, mainly granule to sand-sized inclusions of granite-granodiorite with biotite or hornblende. Randomly oriented, their shape is equant or elongate, while the edges are mostly sub-rounded, sub-angular and rounded. Plagioclase, quartz, quartz schist, muscovite, biotite, volcanic rock, and hornblende are common in this group. They have equant and elongate shape with sub-angular, sub-rounded, angular and rounded edges. Fabric III also contains poorly sorted inclusions of gneiss with quartz and feldspar, sandstone, mudstone, polycrystalline quartz and micaschist with sub-rounded, sub-angular, rounded and angular edges, in equant or elongate shape. The grain-size distribution is unimodal, bimodal, trimodal or polymodal.

Fabric IV: Granite and granodiorite, quartz, muscovite, plagioclase

This fabric (Figs 8d and 8e) was observed in ten samples of Middle Bronze Age and Final Bronze Age chronology. The matrix is either homogeneous or heterogeneous; it has a blackish-brown, optically active matrix. A heterogeneous matrix was recorded in two specimens of this fabric (GE18, GE20). Different clay domains, possible evidence of mixing, were noted in sample GE27. The voids comprise randomly oriented, sub-parallel and parallel channels and vesicles, ranging in size from 0.05 to 1.4mm. The dominant presence of granite and granodiorite with biotite or hornblende, quartz, muscovite and plagioclase characterizes this fabric. The particles are randomly oriented, equant or elongate, with sub-angular, sub-rounded and angular edges. The poorly sorted inclusions include microcline, mudstone and lava particles with equant or elongate shapes and sub-angular to rounded edges. The grain-size distribution of ceramic paste of Fabric IV is unimodal, bimodal, trimodal or polymodal.

Fabric V: Granite

The fabric (Fig. 8f) is documented in three Middle Bronze Age samples. Their homogeneous matrix shows optical activity and is brown, yellow and black in colour. The voids are channel- and vough-shaped, randomly or sub-parallel oriented and vary in size from 0.05 to 1mm. Fabric V is characterized by the presence of granite. Granite particle shapes are equant and elongate with sub-rounded and sub-angular edges. Quartz and quartzite inclusions are common in this group, and are equant and elongate with sub-angular and sub-rounded edges. Finally, inclusions of biotite, muscovite, plagioclase, microcline, metapelite, orthopyroxene and pyroxenite complete the lithological assemblage of Fabric V. These inclusions are equant and elongate in shape, and characterized by sub-angular, sub-rounded, angular and rounded edges. A unimodal and bimodal grain-size distribution is a feature of the ceramics of this group.

Discussion

Exploitation of natural resources

Raw material procurement by Middle and Final Bronze Age people using Eremita Cave for burial purposes may be inferred based on petrographic data acquired as part of the present study. The first type of data to examine in this sense is matrix homogeneity/heterogeneity. Quinn (2013) explains that in most thin sections there are variations in regard to composition, colour and texture of ceramic matrix. This may reflect the homogeneous raw materials (Fig. 9b) or the presence of natural heterogeneity in the raw materials that have not been sufficiently homogenized during clay processing and working. Natural variations in composition are generally common in residual clay deposits formed *in situ*, which may have been bioturbated by the activity of plants and animals living in the upper layers of the soil and regolith (Quinn 2022; Roux 2019). Heterogeneity in the composition of the clay matrix can also be introduced during the ceramic manufacturing process, when two or more different clay raw materials have been intentionally mixed or blended (Arnold 1971; 1972; Quinn 2013; Rice *et al.* 1981; Roux and Courty 1998; Roux 2019; Schiffer and Skibo 1987; Schultz 1971). Whether this heterogeneity is natural or anthropogenic is important to distinguish, both for the provenance and for the reconstruction of the manufacturing technology.

Out of 28 analysed samples, ten present a heterogeneous matrix, regardless of the kinds of aplastic inclusions and the fabric (Figs 9a, 9c and 9d). In the case of the pottery from Eremita Cave, evidence does not allow us to state if the heterogeneity features are of natural or

anthropogenic origin. This could be further investigated in the future through an analysis of local sediments. Therefore, inferences about the type of raw materials used in pottery manufacturing can be only drawn based on another kind of data collected in the study: the characteristics of rock and mineral inclusions and the type of resources available in the region.

Roundness and angularity are grain shape parameters from sedimentology that describe the sharpness of the clast angles (Whitbread 1989). The degree of angularity/roundness of sediments or sedimentary rocks is normally related to the distance the clastic material has been transported from its source (Boggs 2009; Pomerol *et al*. 2015). Sedimentary clay deposits that may contain quartz, feldspar and mica clasts tend to be rounded by water transport, whereas sedimentary clay deposits that may contain quartz, feldspar and mica clasts left by glacial action have angular edges (Quinn 2013).

Fabric I is composed of rounded to angular particles, equant and elongate in shape, and showing a bimodal grain-size distribution. The morphometry of the aplastic inclusions in Fabric I corresponds to the compositional features of fluvial sediments in mountainous contexts (e.g., Carton *et al.* 2009; Fredi and Palmieri 2017) and highlights the possible exploitation of clay originated from the Sesia River's activity.

Fabric II is equally recognized by rounded to angular inclusions with predominant equant sphericity, but some of the inclusions display elongate sphericity. The grain-size distribution of Fabric II is bimodal. Presence of pyroxenite, which does not outcrop in the area of the Lower Sesia Valley point out the use of local glacigenic deposits, formed during Quaternary glaciations (Ivy-Ochs 2015) and being featured by a great variety of lithoclasts from the several complexes of the palaeo-Adriatic margin (Piana *et al.* 2017).

Fabric III shows a lithological assemblage that largely corresponds to the Permian Magmatic Complex and the Serie dei Laghi Complex (granite, granodiorite, volcanic rock, metasediments) and does not present lithotypes from other nappes of the Palaeo-Adriatic unit. Morphometry of aplastic inclusions is mixed: rounded to angular edges, equant and elongate sphericity, and unimodal/bimodal/trimodal/polymodal grain-size distribution. All these characteristics suggest the use of residual clays procured from soils developed on outcrops of the Permian Magmatic Complex and the Serie dei Laghi Complex, which form slopes located at both sides of the Sesia River's winding course (Fig. 4).

Fabric IV presents a very similar lithological assemblage to the ones of Fabric III but lacks the metasediments from the Serie dei Laghi Complex. The morphometry

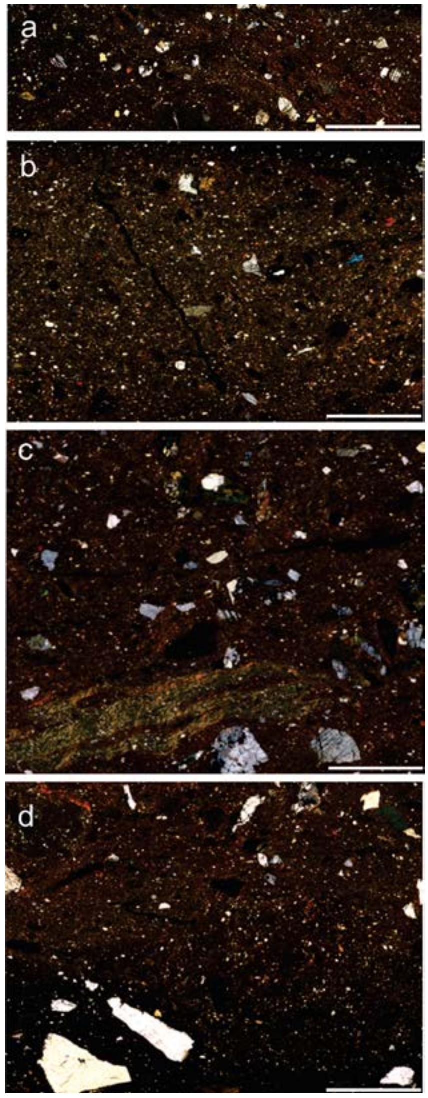

Fig. 9 – Microphotographs under cross-polarized light: Heterogeneous matrix-mixed clay GE27 (a). – Homogeneous matrix GE25 (b). – Heterogeneous matrix GE10 (c). – Heterogeneous matrix GE12 (d). – The length of the white bar is 2mm.

of aplastic inclusions is also similar to the one of Fabric III, being composed of rounded to angular equant and elongate particles, and unimodal to polymodal grain-size distribution (Figs 10b and 10d). Like Fabric III, Fabric IV possibly correlates with a residual clay developed on a granitic bedrock from the Permian Magmatic Complex. However, in this case the area where the raw material was collected saw little or no sedimentological contribution by the Serie dei Laghi Complex (Piana *et al.* 2017).

Fabric V hosts inclusions of various origins: granite from the Permian Magmatic Complex, metasediments from the Serie dei Laghi Complex, and pyroxene-based rocks from other nappes of the Palaeo-Adriatic margin, possibly from the Sesia-Lanzo Zone (Piana *et*

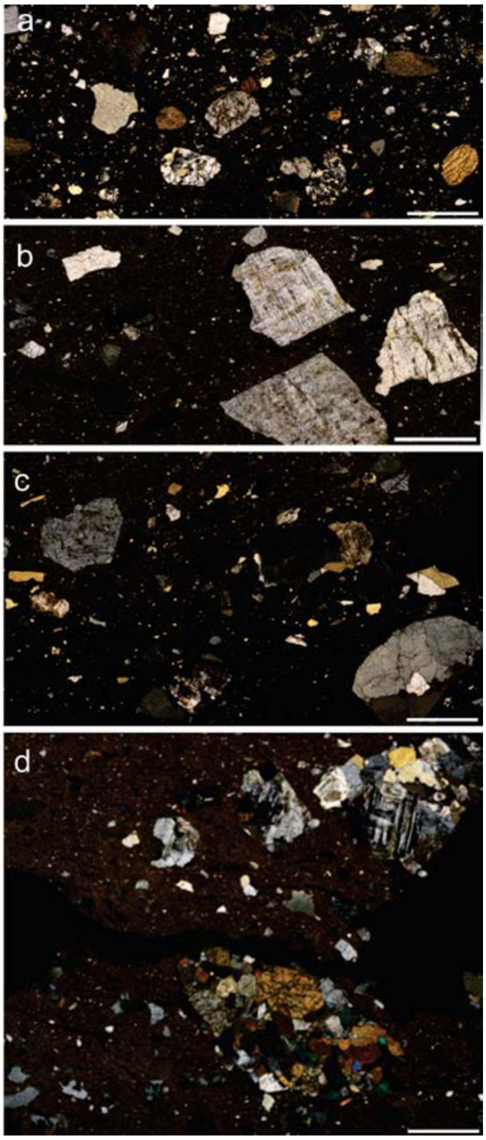

Fig. 10 – Types of grain size distribution documented in 28 samples: GE01; unimodal grain size distribution (a). – GE06; bimodal grain size distribution (b). – GE15; trimodal grain size distribution (c). – GE22; polymodal grain size distribution (d). – Cross-polarized light. The length of the white bar is 2mm.

al. 2017; 2020). The morphometry of aplastic inclusions is indicative of a chaotic pattern of transport (Figs 10a and 10c) (Brodzikowski and Van Loon 1991; Pomerol *et al.* 2015). The lithological assemblage and the shape and size characteristics point out that the clay may have been procured from glacigenic deposits or, most probably, their reworking by the Sesia River.

Inferences about the pottery chaîne opératoire

The petrographic analysis of the pottery from Eremita Cave enabled the acquisition of important information on the ceramic *chaîne opératoire*. With regard to the first step, the acquisition of the raw materials, three main sources are plausible: the fluvial deposits bordering the Sesia River's winding course, the local glacigenic deposits flanking the valley, and the alteration horizons of granitic/volcanic bedrocks from the Permian Magmatic Complex developed on local hills (Fig. 4). Identified raw materials thus reflect the local environment, but the reasons behind this variety of exploited resources remains heretofore unknown.

Regarding the second step of the *chaîne opératoire*, it is possible to assume that the raw materials were likely not modified or manipulated. Notwithstanding the presence of angular particles, generally indicative of rock crushing (Levi 2010; Quinn 2022; Roux 2019; Whitbread 1989), it is more likely that they featured the original clay-rich deposits in the first place. This because of the sedimentological processes related with the mountainous environment (e.g., Brodzikowski and Van Loon 1991; Carton *et al.* 2009; Fredi and Palmieri 2017; Pomerol *et al.* 2015) and the fact that particles with angular edges occur along with others showing rounded, sub-rounded, and sub-angular edges that would have been damaged if crushing or powdering of clay had been carried out (e.g., Albero 2014, and references therein).

As far as shaping techniques are concerned, it is possible to draw some – non-conclusive – inferences based on void characteristics (Quinn 2013; 2022; Roux 2019). Large transversal voids in samples GE12, GE17, GE25, GE26, and GE28 represent gaps between adjacent pieces or 'crumbs' of clay, if not coils or patches, that have not completely closed during the forming process and may be indicative of the employ of the coil technique. Furthermore, elongate voids in ceramics from Eremita Cave are occasionally parallel oriented (Fig. 11b), which may be indicative of the paste having been subjected to compressive and/or shear stresses due to the application of physical force by hand or with a tool that forced the voids to align. Therefore, techniques such as beating/paddling may also have been applied. Other voids, randomly oriented and vughular in shape are most likely related with the drying process, due to the shrinkage of clay as it loses absorbed water, as well as with the firing process (Orton *et al.* 1993; Orton and Hughes 2013; Quinn 2013; Rice 1987; Roux 2019; Stoltman 1991; Stoltman and Mainfort 2002; Stoltman 2015; Whitbread 1995).

With regard to the firing process, the optically active matrices of all 28 samples indicate that the firing temperature was surely <800–850°C (Albero 2014; Quinn 2013; 2015; Velde and Druc 1998). The process of sintering of the matrix may have started but was not completed, as the groundmass preserves its

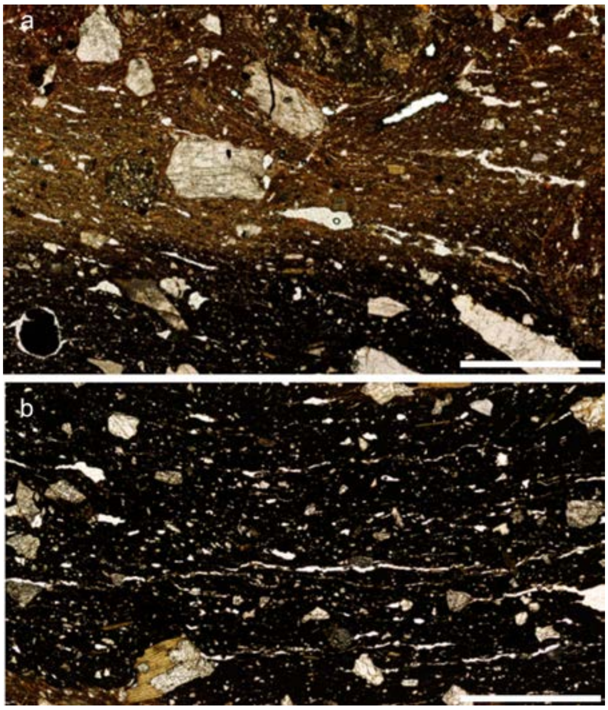

Fig. 11 – Microphotographs showing void orientation: Random orientated voids of GE12 (a). – Parallel oriented voids of GE04 (b). – Plane polarized light. The length of the white bar is 2mm.

birefringence and clay minerals are not fused together or melted. In addition, no mineralogical change generally occurring at 800°C and discussed in the literature (Gliozzo 2020, and references therein) was detected. Finally, void characteristics also support a firing temperature surely <800–850°C, as vescicles are very rare and there were no blisters (Tite *et al.* 2001).

Concerning the firing atmosphere, the brown, orange and red colours that were observed in 15 ceramic thin sections from Eremita Cave (GE06, GE08, GE09, GE10, GE12, GE13, GE14, GE18. GE20, GE21, GE22, GE23, GE25, GE26, GE27) are indicative of mostly oxidizing conditions (D'Anna *et al.* 2011; Echallier 1984; Picon 1973; Rice 1987). These conditions determine if the iron is oxidized to ferric minerals such as haematite (Fe_2O_3), a process that takes place above *c.* 600°C (Quinn 2013). However, the darker colours of the remaining 13 samples (GE01, GE02, GE03, GE04, GE05, GE07, GE11, GE15, GE16, GE17, GE19, GE24, GE28) show predominant reducing firing conditions (D'Anna *et al.* 2011; Echallier 1984; Picon 1973; Rice 1987), in which iron exists as dark ferrous minerals such as magnetite (Fe_3O_4) (Quinn 2013). Dark grey or black cores in oxidized ceramics having reddish or brownish surface colours are documented in five thin sections from Eremita Cave (GE08, GE21, GE22, GE25, GE27) and may be interpreted as resulting from short firing times, when oxygen has not penetrated the mass sufficiently to remove carbon (organic matter) (Quinn 2013). A similar effect can be achieved in ceramics fired under reducing conditions which are then allowed to cool in air, although there may be a sharper delineation between the margin and the core (Quinn 2022; Rice 1987; Roux 2019). This is the case for five thin sections from Eremita Cave (GE02, GE04, GE05, GE11, GE17).

Finally, as regards the place of production, it is possible to state that the pottery was not manufactured in the vicinity of the cave for multiple reasons: i) the cave's interior and outside spaces are not sufficiently spacious, and there is no water flow at a close enough distance to serve the manufacturing process; ii) there is no evidence of pottery production in the cave, nor outside; iii) documented raw materials were procured downhill Mount Fenera and are not likely to have been brought uphill. Hence, the pottery, linked to the burial site of Eremita Cave, was brought into the cave from one or multiple – heretofore unknown – settlement or production sites, possibly located in the Lower Sesia Valley.

Conclusions

The petrographic study of Middle and Final Bronze Age pottery from Eremita Cave allowed to answer questions concerning the pottery production and exploitation of natural resources by the communities living in the Lower Sesia Valley during the second half of the 2nd millennium BC and the beginning of the 1st millennium BC. Analysed ceramic containers cluster into five fabrics that all revealed to result from the exploitation of raw materials located in the vicinity of Mount Fenera, downhill from where the studied cave opens. The different types of paste testify to the use of different sources: fluvial, glacigenic, and *in situ* alteration deposits. Regarding the different steps of the ceramic *chaîne opératoire*, it was possible to draw the following conclusions:

- The acquisition of the raw materials involved procurement from different sources: the fluvial deposits bordering the Sesia River's winding course, the local glacigenic deposits flanking the valley, and the alteration horizons of granitic/volcanic bedrocks from the Permian Magmatic Complex developed on local hills. The reasons behind this variety of exploited resources remains unknown.
- Raw materials were likely not modified or manipulated, as the variety of lithic inclusions and of their morphometric characteristics are most probably related to local geology rather than to any activity by the potters.
- Evidence related to the shaping operations suggest junction of 'crumbs'/coils/patches of clay and, possibly, beating/paddling.

– The firing temperature did not definitively reach 800°C, as the process of sintering of the matrix may have started but was not completed. The firing atmosphere was mostly oxidizing or reducing, depending on the analysed samples. Dark grey or black cores documented in few samples may be indicative of a short firing time.

To conclude, the pottery was not likely produced in the vicinity of the cave and was brought there from one or multiple – heretofore unknown – settlement or production sites, possibly located in the Lower Sesia Valley.

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Sentier sacré avec source du site archéologique de Montagna Vecchia di Corleone (Sicile, Italie)

Angelo Vintaloro

The area halfway up the western side of Montagna Vecchia is crossed by a sacred path dedicated, almost certainly, to the cult of Demeter, which was by far the most practised cult in the archaeological sites of this area. This is also confirmed by subsequent archaeological work survey work and by the discovery of the sanctuary located in the Santissimo Salvatore quarter, in which exclusively clay statuettes of this deity were found. From the northern access point, hidden between cliffs and rocks, we find the signs and symbols that bring us back to the essence of the culture of a people. The scrupulous and methodical archaeological research activities reveal the roots of a cultural-ritual baggage that so far has received little attention. The rock-cut architecture mirrors the morphological image of the vulva. Everything refers to propitiatory fertility rites, in which practices dedicated to the female deities are expressed. A clear sign of this is the presence of the well/womb which is the symbol of Mother Earth, of the Goddess who gives birth to life.

Keywords: Corleone, sacred path, spring, Demeter

La zone à mi-hauteur du côté ouest de la Montagna Vecchia est traversée par un chemin sacré dédié, presque certainement, au culte de Déméter, qui était de loin le culte le plus pratiqué dans les sites archéologiques de cette zone. Ceci est également confirmé par les travaux archéologiques ultérieurs et par la découverte du sanctuaire, situé dans le quartier de Santissimo Salvatore, dans lequelle exclusivement des statuettes en argile de cette divinité ont été trouvées. À partir de l'accès nord, caché entre les falaises et les rochers, nous trouvons les signes et les symboles qui nous ramènent à l'essence de la culture d'un peuple. Les activités de recherche archéologique scrupuleuses et méthodiques ont révélé les racines d'un bagage culturel-rituel qui n'a que peu attiré l'attention. L'architecture de la cavité rocheuse reflète l'image de la vulve dans sa structure morphologique. Tout renvoie aux rites propitiatoires de fécondité, dans lesquels s'expriment les pratiques dédiées aux divinités féminines. Un signe clair en est la présence du puits/utérus qui est le symbole de la Terre Mère, de la Déesse qui donne naissance à la vie.

Mots-clé : Corleone, sentier sacré, source, Déméter

Montagna Vecchia'nın batı yakasının yarısına kadar olan alan, neredeyse kesin olarak, bu bölgedeki arkeolojik yerleşmelerde en çok uygulanan kült olan Demeter kültüne adanmış kutsal bir yolla kesişmektedir. Bu durum, daha sonraki arkeolojik yüzey araştırması çalışmaları ve Santissimo Salvatore mahallesinde bulunan ve sadece bu tanrıya ait kil heykelciklerin bulunduğu kutsal alanın keşfi ile de doğrulanmıştır. Uçurumlar ve kayalar arasına gizlenmiş kuzey erişim noktasından, bizi bir halkın kültürünün özüne geri götüren işaret ve sembolleri buluyoruz. Titiz ve metodik arkeolojik araştırma faaliyetleri, şimdiye kadar çok az ilgi gören kültürel-ritüel bir bagajın köklerini ortaya çıkarmaktadır. Kayalara oyulmuş mimari, vulvanın morfolojik görüntüsünü yansıtmaktadır. Her şey, kadın tanrılara adanmış uygulamaların ifade edildiği bereket ayinlerine gönderme yapmaktadır. Bunun açık bir işareti, Toprak Ana'nın, yaşamı doğuran Tanrıça'nın sembolü olan kuyunun/rahim'in varlığıdır.

Anahtar Kelimeler: Corleone, kutsal yol, pınar, Demeter

La zone à mi-hauteur du côté ouest de la Montagna Vecchia est traversée par un chemin sacré, dédié, presque un lieu, au culte de la déesse Déméter qui représentait de loin le culte le plus pratiqué dans les sites archéologiques de cette zone. Cet élément est également confirmé par la recherche de la dalle de surface, des fouilles archéologiques effectuées à Pizzo Spolentino en 1993, et de la découverte de la zone sacrée, située dans le quartier Santissimo Salvatore, entre la rue homonyme et le surplomb de la Rocca dei Maschi, dans laquelle on ne trouve que des statuettes d'argile de cette divinité. À partir de l'accès nord, caché parmi les falaises et les rochers, vous trouverez les signes et les symboles qui nous ramènent à la culture d'un peuple. Le chemin souvent tortueux est en pavés, en partie encore bien conservés, avec des marches et des murs de confinement.

La présence dans la région de tombes de l'âge du Bronze (Tusa 1992, p. 629–663), nous amène à penser que le culte de Déméter, de l'époque classique, a hérité de ces réminiscences de l'époque mycénienne, qui dans cette région ont forcé sa présence, comme une émanation des colonies de du sud-est de la Sicile. Les activités de recherche archéologique scrupuleuses et méthodiques, récemment menées dans la région corléonaise, offrent des révélations importantes sur les racines d'un bagage culturel et rituel, qui n'a suscité que peu d'intérêt (Scuderi et al. 1997). Le mythe et le rituel constituent souvent une clé fondamentale

a

b

Fig. 1 – Grotte de Déméter, tunnel (a). – À l'intérieur de la grotte de Demeter, point central du culte (b). – (Photos : Projet archéologique de Corleone).

pour comprendre une structure sociale du tissu socio-économique d'une réalité communautaire. La mythologie et les rituels ancestraux qui y sont liés peuvent en dire long sur l'histoire liée aux sites de la Montagna Vecchia, et sur les chemins qui, partant de cette zone anthropisée à l'époque préhistorique, nous conduisent à la civilisation corléonaise. À la suite des découvertes des sites, qui du fait de leur morphologie renvoient à d'anciennes pratiques rituelles et cérémonies sacrées des Ve-IVe siècles avant J.-C., il est éclairant de retracer le mythe grec de Déméter et de sa fille Coré (Vintaloro 2020).

La séquence mythologique raconte que le dieu des enfers et des morts, Hadès, épris de la beauté de Coré, kidnappe la jeune fille en l'entraînant dans son enfer des ombres. Dans l'obscurité de la terre, il lui offre sournoisement les graines de grenade qui forcent éternellement ceux qui se nourrissent de ces fruits vers l'enfer. Pendant neuf jours, sa mère Déméter se lance à la recherche désespérée de sa fille. Puis, la déesse de l'agriculture, qui a pris conscience de l'enlèvement de la jeune fille et saisie de colère, menace le réveil de toutes les formes de vie et de végétation, obtenant le retour de la jeune fille de Zeus. Celle-ci, devenue Perséphone, pourra vivre six mois sur terre, pour retourner dans les profondeurs du sous-sol, où passeront les six autres mois du cycle annuel, marquant l'alternance des temps saisonniers. Le mythe est clairement lié au retour inexorable des saisons, au renouvellement cosmique de la vie, à la régénération cyclique des champs et du monde végétal. La figure de Déméter, déesse de la fertilité et des récoltes, peut être rattachée aux divinités les plus ancestrales.

Le chasseur-cueilleur, avec le passage au Néolithique et avec l'introduction de l'agriculture, devenu cultivateur, commence à ressentir le besoin de se tourner vers la Terre Mère, la Dame de la vie et de la mort, dispensatrice du don de la fertilité ; elle s'adresse donc au transcendant par des gestes rituels propitiatoires d'abondance. Le chemin sacré découvert lors de recherches récentes près de Montagna Vecchia est probablement lié aux divinités archaïques du cycle de vie de la terre, attribuables à l'âge du Bronze, puis au culte de Déméter et aux mystères éleusiniens. Le circuit probablement parcouru par des prêtres et des « initiés », impliquait le passage dans un hypogée dans lequel se trouvait ce qui semble correspondre à un puits sacré. La sacralité du lieu est accentuée par le fait que, à l'intérieur du site souterrain, il y a des niches dans les murs qui contenaient probablement des statuettes cultuelles et des objets votifs. L'architecture de la cavité rocheuse reflète l'image de la vulve dans la structure morphologique. Tout renvoie aux rites propitiatoires de fécondité, dans lesquels s'expriment les pratiques dédiées aux divinités féminines. Un signe évident en est la présence du puits/utérus qui est le symbole de la Terre Mère, de la Déesse qui donne naissance à la vie.

En continuant sur les traces qui témoignent de la présence du chemin rituel dans la zone de la Piazzetta del Pino, vous arriverez à ce que, selon la tradition orale, on appelle la « Grotte du trésor » ou « Grotte des voleurs » : une grotte rocheuse à l'intérieur de laquelle sont creusées des marches qui mènent dans l'espace en dessous par un trou, comme s'il s'agissait d'un acte de purification où l'on entre pécheur et on en sort expié (fig. 1 a–b, 2 a). Une légende locale raconte que des pièces d'or étaient cachées dans cette grotte rocheuse, que seule une vache aurait pu extraire. Selon le conte populaire, quiconque pénétrait dans cet endroit mystérieux était bloqué par un mur qui l'empêchait de s'échapper avec le trésor empoché. Cette grotte ne pouvait être abandonnée par les accapareurs qu'après avoir déposé à nouveau les pièces à leur place. Par conséquent, personne n'a pu extraire cette richesse : il manquait la figure

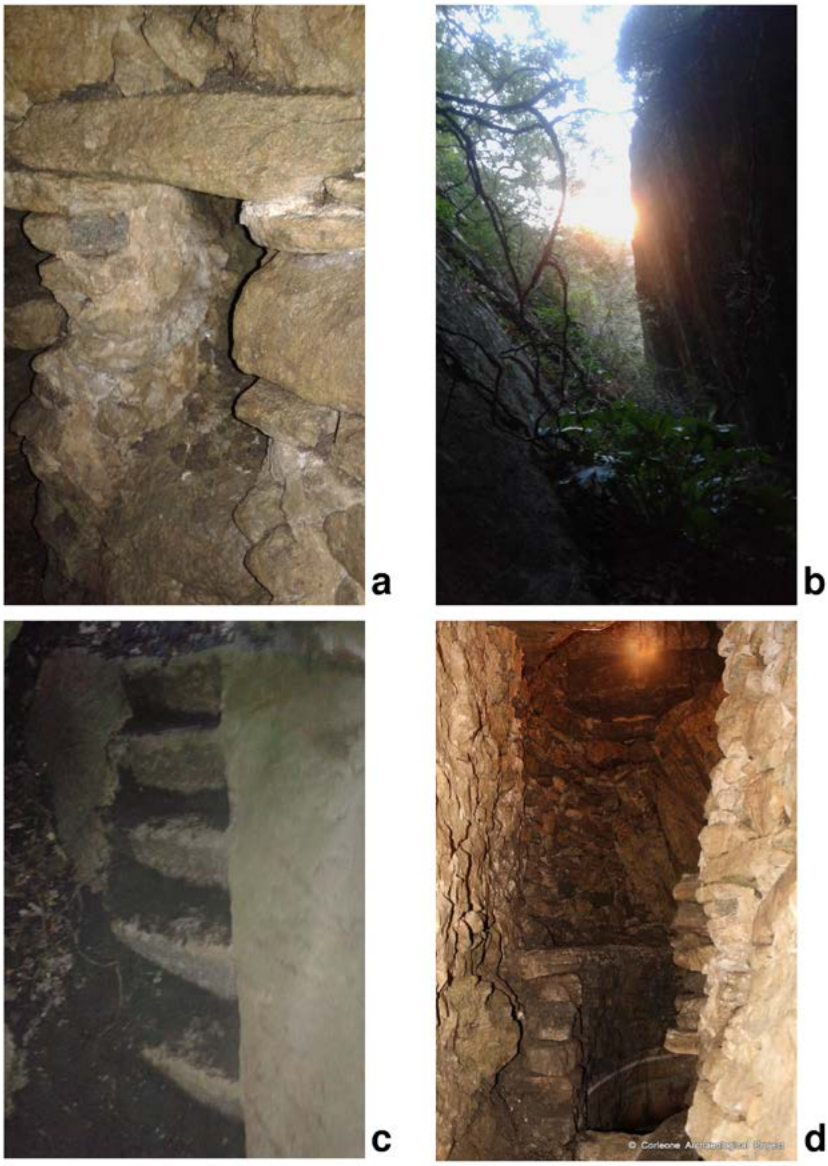

Fig. 2. – Niche à l'intérieur de la grotte (a). – Couloir à l'extérieur de la grotte sacrée (b). – Chemin sacré du couloir artificiel (c). – Grotte de Déméter, sièges où s'asseyaient les prêtres (d). – (Photos : Projet archéologique de Corleone).

essentielle pour pouvoir rompre le charme. Le récit continue d'attirer l'attention sur un groupe de jeunes. Ces derniers se retrouvèrent en train de jouer, jetant de l'argent à l'extérieur de la caverne obscure, et assistèrent au retour prodigieux des pièces à l'intérieur. Pendant ce temps, une vache franchit le seuil de la grotte et, après s'être roulée par terre, en ressortit avec une pièce attachée à son dos. Ce n'est qu'après cet événement curieux que les garçons ont réussi à extraire le trésor et à vivre une vie riche et prospère. Mythe et rite retrouvent correspondance, ils convergent vers la même solution. La grotte était très probablement l'un des éléments clés des rites agraires et du culte dédié à Déméter. En fait, il y avait deux entrées en elle probablement liées à des actes cérémoniels purificateurs : les adeptes, attribuables aux garçons de la narration, pénétraient dans l'obscurité des ténèbres pour s'élever à une nouvelle vie (fig. 2 b).

Entre autres choses, la déesse grecque Héra, la sœur de Déméter, était la patronne du mariage et son symbole était la vache. D'après les écrits de Valenti, il est clair que la vache était probablement représentée sur l'une des pièces de monnaie de la Montagna Vecchia. Tous ces éléments, liés à l'exclusivité des découvertes archéologiques de Montagna Vecchia et du territoire, ont renforcé l'idée que tout cela remonte à la déesse Déméter, même si seule la fouille archéologique pourra donner la dimension définitive de ce qui est en tout cas présenté comme un artefact aux formes typiques d'un chemin sacré, qui partait du plateau et descendait du côté nord-est de la montagne, pour parcourir environ 2 km jusqu'à la grotte en question (fig. 2 c), où dans la grotte en forme de vagin l'eau coule toute l'année et il y a des sièges où les prêtres étaient mis (fig. 2 e). Ces eaux abondantes étaient utilisées à des fins domestiques et pour l'irrigation des champs qui alimentaient directement la ville.

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An archaeology of gesture? Reconstructing some Iron Age fighting techniques

Guillaume Reich

For the archaeologist, the study of warfare in Celtic societies during the La Tène culture (Later Iron Age) is primarily based on archaeological evidence. While it may be tempting to use depictions of weapons and warriors produced by the Celts or their contemporaries to gain a better understanding of the phenomenon, these images present a potential source for determining combat gestures. However, this raises the issue of gaps in both the upstream and downstream moments of a complex motor sequence that is frozen in material. Clear interpretation of these sequences allows us to catch a glimpse of the ideological biases conveyed by these martial representations.

Keywords: Weaponry, combat, archaeology of gesture, chronophotography, iconography

Pour l'archéologue, l'étude de la guerre dans les sociétés celtiques du deuxième âge du Fer repose avant tout sur des témoignages archéologiques. S'il peut être tentant d'utiliser des représentations d'armes et de guerriers produites par les Celtes ou leurs contemporains pour mieux comprendre le phénomène, ces images présentent une source potentielle pour déterminer les gestes martiaux. Cependant, cela soulève la question des lacunes dans les moments en amont et en aval d'une séquence motrice complexe qui est figée dans la matière. Une interprétation claire de ces séquences permet d'entrevoir les biais idéologiques véhiculés par ces représentations martiales.

Mots-clés : Armement, combat, archéologie du geste, chronophotographie, iconographie

Arkeologlar için, Geç Demir Çağı'nda Kelt toplumlarında savaşın incelenmesi öncelikle arkeolojik kanıtlara dayanmaktadır. Bu olguyu daha iyi anlamak için Keltler ya da çağdaşları tarafından üretilen silah ve savaşçı tasvirlerini kullanmak cazip gelse de, bu imgeler savaş jestlerini belirlemek için potansiyel bir kaynak sunmaktadır. Ancak bu, materyal içinde donmuş olan karmaşık bir motor dizisinin hem yukarı hem de aşağı yöndeki momentlerinde boşluklar sorununu gündeme getirmektedir. Bu sekansların net bir şekilde yorumlanması, bu askeri temsiller tarafından aktarılan ideolojik önyargılara bir göz atmamızı sağlar.

Anahtar Kelimeler: Silah, savaş, jest arkeolojisi, kronofotografi, ikonografi

Armed violence and warfare played fundamental roles in Celtic societies during the La Tène culture. For the protohistorian, the study of these phenomena is primarily based on archaeological evidence, particularly the numerous weapons discovered during excavations of burials, sanctuaries, war trophies or hoards/wealth deposits. However, these objects cannot be viewed simply as fixed material. Archaeology is a human science, and understanding the use of an object requires addressing essential anthropological issues (Archambault de Beaune 2000; Van Andringa 2021). Thus, a strictly materialistic approach to *militaria* seems obsolete. One could simply note, for example, that an iron object was discovered at the eponymous La Tène site, which is identified, based on morphological proximity to more recent European sword types, as a sword (Fig. 1). It can be assumed that the handle is used to hold the object, the edges of the blade are used to cut, and the point is used to possibly pierce an opponent. However, it should also be noted that this form of sword appears in certain ancient iconography (Greek, Roman, Gallic, *etc*.). These images, stamped on coins, carved on bas-reliefs or statues, or engraved on other artefacts, serve to justify and explain martial gestures.

However, the images produced in Antiquity raise several questions regarding the credibility of the conveyed message. It can be hypothesized that these images serve a discourse and are based on a real but exaggerated feature, a *topos*, or even disseminate a false point of view, possibly for propaganda purposes. Thus, the reliability of the representation is a fundamental question for figurations of fight/battle scenes. Are these images representative of the actual way of fighting, or are they an ideological vector that does not reflect the martial reality? Are these scenes realistic, and if so, where do they fit into the martial sequence? Are the choices made on these friezes the ones that allow for the identification of warriors' gestures with certainty? In other words, this raises the problem of representing a complex movement at each stage of its evolution (or how to compensate for the absence of parataxis, cf. Anglo 2011: 8; Baudet 2013: 109): what are the gestures upstream and downstream of the representation that have been chosen and frozen in stone or metal? All these

Fig. 1 – Sword with notches concentrated between the middle and three quarters of the blade. La Tène (CH), Neues Museum Biel, no. 2745. – (Photo: ADB, Badri Redha).

questions underline the need to better understand the art of combat.

A comic strip can afford to be imprecise in its gestures to remain expressive, because it makes use of artifice. The characters have explicit postures, and we know they are running. However, this identification is largely possible due to motion lines. If we remove these drawing conventions, the impression of movement (and speed) is already less obvious. However, in the case of ancient iconography, these procedures are not used. This invites more careful observation and more realistic reproduction of gestures, notably by choosing the moment T to illustrate a movement.

Looking at a chronophotograph (a "*sequence of photographic images taken at very short intervals of time in order to analyse the movement of a subject*" ; Chik 2011: 85) that shows the different stages of a pole vault ('*Saut à la perche'* by Étienne-Jules Marey), it is clear that it is the collection of these gestures, or "*micro-movements that can be isolated from each other*" (Baudet 2013: 114), that best represents the action of the pole vaulter (Fig. 2). However, if we were to choose only one image due to a limited space for representation, as is the case with stone sculpture or engraving on a metal object, we would discard the starting movement, which corresponds to the run-up and would not be very comprehensible. Similarly, we would eliminate the last images, which correspond to the fall and the bounce without the characteristic pole. By selecting the third or fourth snapshot of the chronophotography, taken in the direction of the race and including the main tool (*i.e.*, the pole), we would optimize the choice, as the gesture would be more explicit than the take-off or landing.

The choice of the correct moment is far from insignificant and remains challenging. This difficulty increases as we move away from a discipline that we

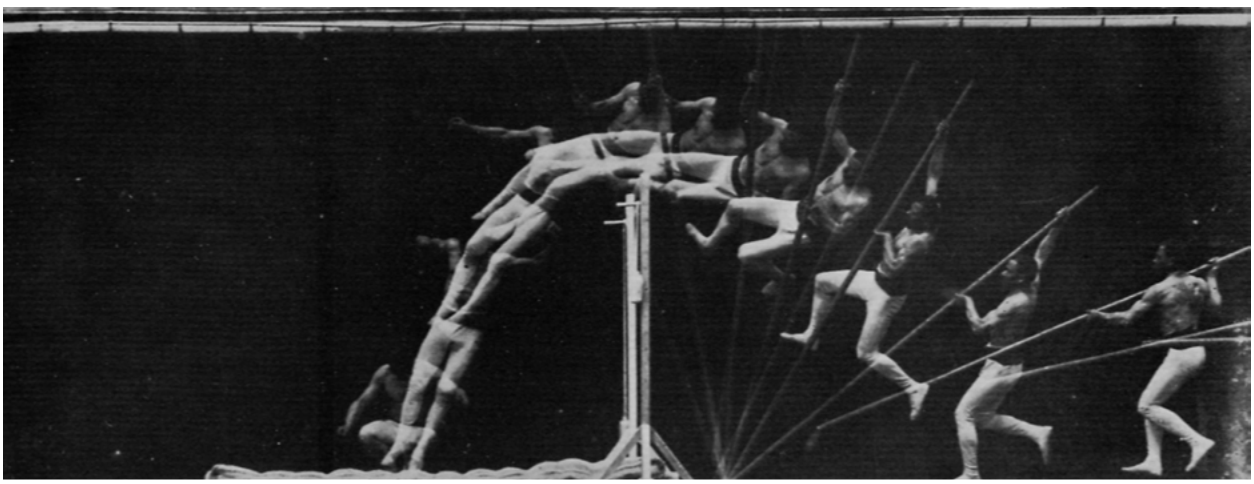

Fig. 2 – Étienne-Jules Marey (1830–1904), '*Saut à la perche*', c. 1890. – (Chronophotograph, glass positive, 4,7 × 8,7cm).

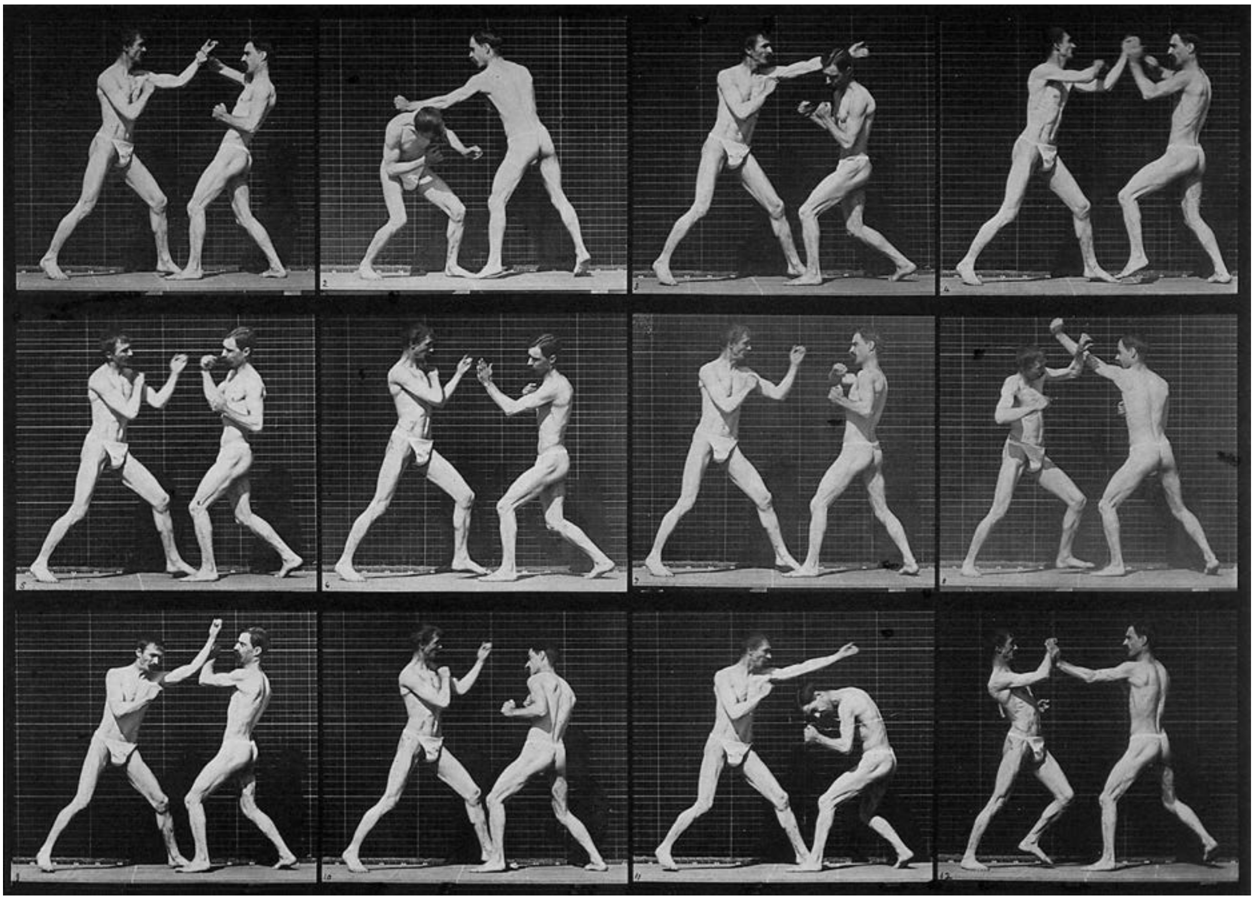

Fig. 3 – Eadweard James Muybridge (1830–1904), '*Boxing, open hand*', 1887. – (Collotype, plate no. 336, 22.7 × 32.3 cm, Washington, The National Gallery of Art).

know, either through observation or practice, and as the movements become more complex. For example, if we consider Eadweard James Muybridge's collotype '*Boxing, open hand*', which features boxers, it is almost challenging to identify the most representative scene of their discipline or fight (Fig. 3). Each conveys a different impression, through the varying body postures of the two opponents or the significance of the props. The second image could be interpreted as a different martial discipline if the context were different, such as with a Japanese kimono instead of a loincloth...

This chronophotograph ('*Une attaque par coup droit en fente*' by Georges Demenÿ) of a modern fencer also illustrates the difficulty in choosing a particularly representative image of the swordsman (Fig. 4). In a comic strip, the running movement is easily recognized as we have all experienced these movements. With modern fencing, we can either know it or have had the opportunity to observe it (or at least, we would have had the oppotunity).

But what about the martial tradition of the Iron Age Celts, whose chain of learning has been interrupted and can usually only be understood through archaeological artefacts? If we limit ourselves to traditional methods, such as typo-chronological description, the discourse quickly becomes limited. However, by exploring other methodological issues, it is possible to develop an archaeology of gesture and 'bring these weapons to life'. In our research, we proposed a reading of traces of wear and damage enriched by martial experiments and nourished by different methods such as forensic sciences, ethno-archaeology, biomechanics, applied mathematics, and materials engineering (Reich 2018; 2022). This allowed us to determine a set of plausible and credible gestures. This method starts with constants between the Iron Age and the 21st century: the biomechanical possibilities of the human body and the intrinsic mechanical qualities of weapons. Thus, if we take the case of the Celtic sword, physical measurements and concrete practice quickly reveal its dynamic properties, such as optimizing the grip, identifying the most efficient striking zone, and determining the type of blow that seems most adapted to the weapon. It is worth noting that ancient iconography was not used as a primary source for reproducing these gestures in order to avoid circular reasoning. We retained the gestures corresponding to (sub)moments of the fight

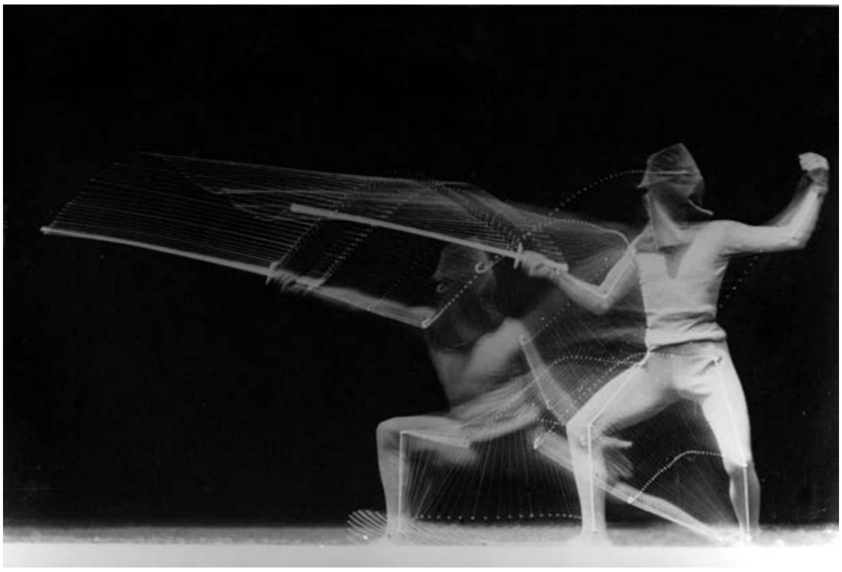

Fig. 4 – Georges Demenÿ (1850–1917), '*Une attaque par coup droit en fente*', 1906. (Fixed-plate chronophotograph).

transcribed in our own drawings because they appeared to us as the most representative of different complex motor sequences. These selected movements correspond to many strong moments that are characteristic of precise technical and tactical intentions, which intervene in the dynamic chronology of the fight, such as offensive, defensive or dodging phases.

Let's illustrate this with two examples. The infantryman on the Bologna felsinian stele (Figure 5), dated to the 5th century BC, appears to hide his sword behind his shield (La Certosa, no. 168: Sassatelli 1983: 132, fig. 4; Andreae 1991: 60). This is a movement that is found spontaneously in the experiments. This gesture is the typical guard posture when one is about to deliver a powerful thrust, hiding one's intentions from the opponent (Figure 6).

The infantryman on the left, possibly depicted on a brass cuirass piece from the 2nd century BC discovered at the 'Lacoste' site in Mouliets-et-Villemartin (Sireix 2011: 52), also assumes a very characteristic guard posture (Figure 7). This movement is not passive; it is that of a fighter protecting himself who interacts with his attacking opponent (Figure 8).

Our research has shown that, in most cases, the gestures of the infantrymen represented in ancient iconography can be explained and remain faithful to martial gestures. They are in most cases credible movements.

To make these scenes realistic, key points of the Celtic warriors' martial skills had to be emphasized. Those who depicted and sculpted these scenes, or at least those who commissioned the works, had a perfect knowledge of these movements, the intentions behind their execution, and the succession of the different chronological phases of the fight (such as alternating technical gestures: attack, defence, *etc.*). Similarly, the people to whom these images were addressed had to fully understand these temporalities. Thus, the message was perceptible in its entirety by the reader of the image, whose paradigm was undoubtedly slightly different but close enough to that of the commissioner. If the gestural representation can then become a *cliché*, it is not because it is unrealistic but because it diverges from the martial choices (weapons and their technical or tactical uses) made by people from ancient Mediterranean cultures or because of more subtle elements in the physiognomy (such as the frequent nudity of the Barbarians) or in the emotional choice (such as submission or dismay). The image can have biases (whether voluntary or involuntary) but we must look for them outside this gestural choice. The scenes do not insist in devaluing martial postures; on the contrary, the good martial skills of the fighters seem to be even highlighted, perhaps because it enhances the prestige of having sometimes defeated them. It also implies a form of 'respect' for the art of combat. The codes, which must have been common and whose meaning largely escapes us, must have been located elsewhere. The distinction, now possible, between realistic scenes and more grotesque gestures, seems to be a first step in deciphering them. Therefore, it is effective in many cases to use the images to understand the art of combat, which can now be confirmed through practical demonstration, rather than constituting a mere postulate.

Our next work on iconography will consist of an exhaustive analysis of the images, in particular to try to determine the place that realistic martial gestures can have in a propaganda discourse. It will also involve taking advantage of our most up-to-date knowledge of horseback fighting, by analysing the postures of the riders.

Fig. 5 – Felsinian stele from Bologna 'La Certosa', no. 168, side A, lower part (Bologna, Museo Civico).
(Photo: C. N. B., Bologna; after Sassatelli 1983: pl. CXXXII, fig. 4).

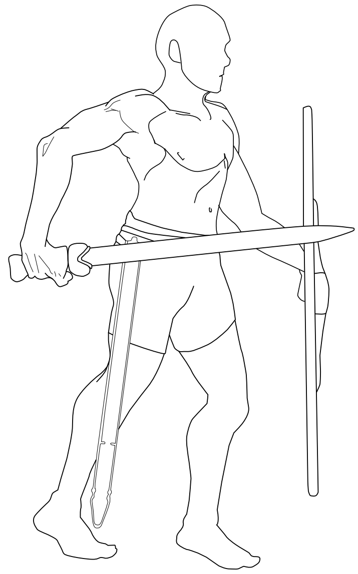

Fig. 6 – Guard posture for the sword thrust/estoc.
(after Reich 2018: 424, fig. 134).

Fig. 7 – Part of a breastplate, Mouliets-et-Villemartin 'Lacoste', no. 1005.7.0.1.
(Photo: P. Galibert, INRAP; after Sireix 2011: 52).

Fig. 8 – Sword guard posture.
(Photo: G. Reich).

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Water Supply and Water Management in the Metal Ages gathers papers originally presented at the Metal Ages 2022 colloquium, hosted by the Archaeology Department of Bilkent University, Ankara and bringing together the UISPP's Scientific Commissions 'Metal Ages in Europe and the Mediterranean' and 'Archaeometry of Prehistoric and Protohistoric Inorganic Artefacts, Materials and their Technologies' for their respective annual meetings.

Five of the papers included here focus specifically on water supply and water management. Others cover copper metallurgy, pottery studies and fighting techniques, and overall they range chronologically from the Chalcolithic to the Late Iron Age, and geographically from Iran to Iberia. A significant number of papers cover topics focusing on artefact archaeometry, due to the participation in the Ankara colloquium of many colleagues from the UISPP's Archaeometry commission.

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